

## Chapter XIII

# Space Station: A Visionary Program in a Pragmatic Era

*“A major attribute of the Space Station program is the flexibility to adapt to changes in funding.”*

Space Station Phase A Report, November 1968

From the time when people began to dream of vehicles to escape Earth’s gravity, two images dominated their thoughts: rockets and space stations. Marshall Space Flight Center (MSFC) has played a central role in the realization of both dreams, building Apollo’s Saturn rockets and using the S-IVB stage as the basis for *Skylab*.

Progress toward a permanent Station in orbit was slow, but Huntsville’s space team was at the Center of American dreaming, planning, and development. Perhaps no program shows as well the tortuous path from creative imagination to hardware. Marshall’s involvement with Space Station encompasses von Braun’s visionary sketches of the 1950s; conceptual studies in the 1960s; management of *Skylab*, America’s first Space Station; development of payloads suitable for Space Station experimentation; management of major portions of NASA’s *Space Station Freedom* program; and the political, budgetary, and organizational struggles of the 1980s and 1990s.

Space Station has been NASA’s most visionary and frustrating program. The program had the misfortune of maturing at a time when the nation was not seeking visionary quests, but rather trying to trim federal expenditures and evaluating programs on the basis of cost effectiveness. Space exploration and the Space Station were hard to justify with quantifiable standards. Bob Marshall, who directed MSFC’s Program Development directorate, explained the dilemma: “The main reason we’re building the Space Station is not because of what I can tell you we’re going to do with it, which I can’t. The main reason is because

I can't tell you what we're going to do with it. And if you don't ever do it, you'll never find out."<sup>1</sup>

As in most post-Apollo programs, costs determined what NASA could do. Limited budgets, constantly under revision, forced the Agency to follow a "design to cost" approach for Space Station. This philosophy affected every aspect of the program including the configuration, division of labor, management approach, contracting, and schedule.

Design to cost led to programmatic complexity, bureaucratic infighting, and unprecedented political intrusion. Unlike the straightforward division of labor between Marshall and Houston under Apollo, NASA divided Space Station work among several Centers, and made the split on the basis of overlapping systems rather than separate hardware. This made systems integration difficult, and spawned debates between Centers, and between the Centers and Headquarters and led to political controversies that by the early 1990s threatened to kill the program.

Many NASA veterans insisted that the programmatic challenges of Space Station were greater than the technological barriers. This was a great source of difficulty for Marshall; the Center was accustomed to meeting technological challenges, but programmatic issues were often beyond its control. Initially, Marshall was at the center of the Space Station program, sharing the largest development role in a roughly equal split with Johnson Space Center (JSC). Nonetheless, because of managerial, political, and budgetary problems, the Center often found itself buffeted by winds from Washington.

### **Early Visions**

Although fanciful notions of Space Stations appeared in fiction in the 19th century, it was not until the early 20th century that people with scientific training speculated about platforms to establish a permanent human presence in space. Pioneers in rocketry who speculated about space stations included the Russian Konstantin Tsiolkovsky in 1903, the American Robert Goddard in 1918, and the German Hermann Oberth in 1923.<sup>2</sup>

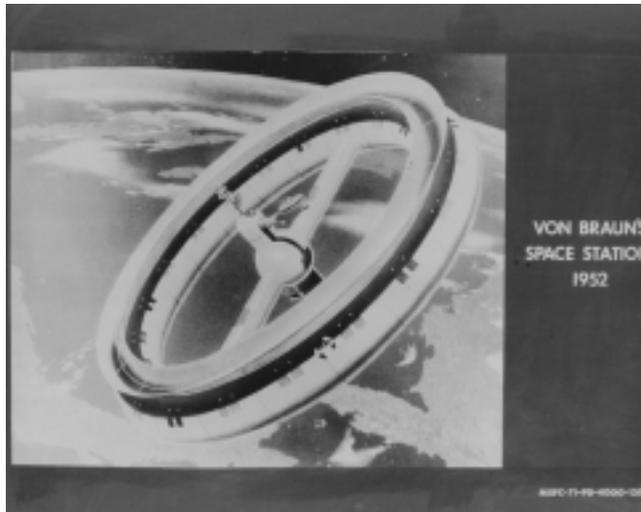
In speeches beginning in January 1947 and in his illustrated article in *Collier's* in 1952, Wernher von Braun advocated a space station for exploration,

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meteorology, navigation, and as “a terribly effective atomic bomb carrier.” The *Collier's* conception, a 250-foot wheel in an orbit 1,075 miles above Earth, became the dominant public image of what a space station should look like. Herman H. Koelle, later a von Braun colleague at the Army Ballistic Missile Agency (ABMA) and Marshall, worked with von Braun on investigations of the feasibility of Mars exploration. Koelle proposed a space station design in 1951, a combination observation post, scientific laboratory, and engineering test site.<sup>3</sup>

The von Braun team began working on space station designs while still part of ABMA. Koelle headed the Future Projects Design Branch, which became the Future Projects Office after Marshall joined NASA. “We were one of Dr. von Braun’s favorite little groups down in the bowels of the ABMA,” recalled Frank Williams, who later succeeded Koelle.<sup>4</sup>

Most of Koelle’s young recruits were engineers, but others brought skills in disciplines like life sciences. One of these was John Hilchey, a physiologist who arrived in 1959, and who claimed that his only qualification was that for 25 years “I had read science fiction and dreamed and schemed it.”<sup>5</sup>



*The von Braun Space Station wheel in Collier's, 1952.*

John Massey, author of one of the early ABMA space station studies, arrived at ABMA two years before the establishment of Marshall Space Flight Center. “Ever since I first came here in April of ‘58,” he remembered, the group discussed “various programs of space-based, lunar-based, or space station-type of programs.”

Von Braun and Koelle told the group to start with the premise “let’s envision a space station and what [it] is made up of, what it can perform and not worry too

much about how we would get it up there.” Massey remembered that the group had free rein, and considered “early designs which encompassed everything from von Braun’s wheel on down to virtually every concept you can come up with: globes, a disk, long arms, just everything.”<sup>6</sup>

When the National Advisory Committee for Aeronautics (NACA) asked von Braun to take part in a committee devoted to long-range planning for the national space program, he turned to Koelle’s group. “Several of us from that organization got to work directly with Dr. von Braun to help him put together thoughts and concepts and proposals and reports to take forward,” Williams remembered. “We’d go back and rap among ourselves and come up with ideas and designs and concepts and do performance trades.”<sup>7</sup>

One of the results of such brainstorming was Project Horizon. Koelle’s group brought in representatives of the Army early in 1959 for a 90-day study conducted in a three-story cinder block building that later became Marshall’s Structures Lab. “We went at it night and day,” Williams remembered. “We laid out building a transportation system which did in fact require the use of a space station or transportation node in orbit. It was a filling station in orbit.” The report envisioned operating a 12-man station by 1966.<sup>8</sup>

The report reflected modifications in von Braun’s ideas about a space station that evolved in the 1960s in response to technological changes. The development of intercontinental ballistic missiles rendered the possibility of using a space station as a weapons platform obsolete, and advances in computer and electronic technology meant that people would not be needed for orbital Earth observations. Von Braun believed that a space station might best serve as a “house trailer” for astronauts on their way to the Moon or Mars, or for other activities in space such as the assembly of large spacecraft from components. Other uses would undoubtedly emerge over time.<sup>9</sup>

After President Kennedy committed NASA to a lunar landing program, plans for a station contributed to the Earth-orbit rendezvous (EOR) mode proposal advocated by von Braun, now the director of the Marshall Space Flight Center. Although EOR would not have required a space station, the orbital maneuver necessary to transfer propellant from one Saturn to another would have anticipated the type of activity for which a space station would be suited.<sup>10</sup> “In the very beginning it was envisioned by most people around here that we’d probably go to a space station as a stepping stone to a lunar exploration program,”



### **Space Station in the Shadow of Apollo**

The mode decision forced NASA's hopes for a space station to the periphery. The space station vision clashed with reality, as low priority, sparse funding, and competition from the Air Force limited planning. Rather than abandon plans, the Agency resorted to protracted studies, incremental planning, and Apollo technology to keep space station plans alive.

Marshall, the Manned Spacecraft Center, and Langley Research Center all directed contractor studies, but in light of the "understandable preoccupation with the Apollo mission," funding was meager. NASA decided to split planning into small segments in order to spread spending over a longer period. "That's what I had expected," von Braun remarked. "OMSF just hasn't got the doe [sic]!"<sup>14</sup> Marshall received the smallest portion of study funds allocated by Headquarters—only \$300,000 for contractor work in 1963, less than 10 percent of the money distributed among the three Centers.<sup>15</sup>

Furthermore, the program lacked direction. Joseph F. Shea, who coordinated Space Station planning for the Office of Manned Space Flight (OMSF), found only diffuse support from other Headquarters offices, and even his deputies termed the justification and requirements for station "nebulous."<sup>16</sup>

Prospects for a NASA Station suffered not only from poverty and malaise, but from competition with the Air Force. NASA and the Department of Defense agreed that there should be only one space station to meet both defense and civilian requirements. But they had not agreed who should build it, what form it should take, and who would control it, so the Air Force proceeded with studies for a manned orbital laboratory (MOL). Early in 1963, NASA Associate Administrator Robert C. Seamans, Jr. appointed a special task team to evaluate NASA's plans for a manned Earth orbiting laboratory (EOL), and appointed Marshall's James Carter to the committee. By June, however, it was clear that NASA would not be able to initiate a major new program. Seamans was non-committal when the group presented its report. "NASA HQ is simply very cautious with respect to any new starts in view of Apollo overruns [and] Congress[ional] sentiments," von Braun commented when he received Carter's report. "We must lie low for awhile!"<sup>17</sup>

Budget constraints forced NASA to set priorities, and by 1965 the Agency had to acknowledge that "approved programs are making heavy demands on

limited financial and human resources.”<sup>18</sup> The Agency shelved ambitious plans for large space stations.

The new fiscal environment posed unprecedented challenges to Marshall, but ironically thrust the Center into a leading role in space station planning. MSFC had to contend with declining resources for the decade after 1965.<sup>19</sup> NASA’s need to capitalize on existing programs rather than initiate large new missions offered opportunity, however. It gave birth to the Apollo Applications Program (AAP), under which Marshall developed *Skylab*, and thereby became the only Center to manage a space station program. When NASA revived studies for a large station, Headquarters would not be likely to assign Marshall only a marginal role.

*Skylab* was the major AAP program for both NASA and Marshall, but neither the Agency nor the Center abandoned hopes of building a large manned space station superseding Apollo technology. Von Braun insisted that a large manned space station should be the “next major objective in the manned space flight program.” Not surprisingly, he suggested that the AAP program would be “a logical first step for the generation of the necessary operational experience, knowledge and techniques that are required for the establishment and useful operation of a space station,” an assumption that would place Marshall in the forefront of the next major NASA goal.<sup>20</sup>

NASA continued to refine plans for Station, looking for ways to reduce costs, defining experiments, and adjusting the concept to the expectations of experimenters.<sup>21</sup> Station plans, however, showed the impact of conflicting pressures. Headquarters, caught between Centers that were demanding more and a Bureau of the Budget that delivered less, sent contradictory signals.

For the next two years, Space Station planning reflected the new environment of fiscal austerity. In 1966 a committee headed by Charles Donlan advocated a station manned by 8 to 12 people capable of operating for up to five years, and serviced by vehicles already in NASA’s inventory.<sup>22</sup> NASA requested \$100 million in its FY 1967 budget for Phase B definition studies based on the Donlan report. When the Bureau of the Budget refused to approve funding, NASA continued Phase A conceptual studies out of advanced mission funds during 1967 and 1968.<sup>23</sup> The Phase A study concluded that one of the attributes of Space Station was its “flexibility to adapt to changes in funding,” and showed what it meant by slashing its intended operational life to two years and

reducing its crew to six with a provision that it could be operable with a crew of only three.<sup>24</sup> In six years budget constraints had forced NASA to lower its sights from a 21-man station to one that could be operated by a crew no larger than that of an Apollo capsule.

NASA managers, including Marshall's von Braun, were not accustomed to thinking small, however. In December 1968, Acting Administrator Thomas O. Paine showed his dissatisfaction with the Phase A report by querying Center Directors about the goals, configuration, size, and uses of Space Station. The Center Directors cheered Paine's instinct to seek a bolder concept. Von Braun assured Paine of his support for a "truly forward-looking program."<sup>25</sup>

Marshall wanted to play a central role in the planning for a larger space station. When von Braun assigned William R. Lucas to head the Program Development Directorate in December 1968, he made clear that a major duty of the new entrepreneurial organization was to "'harden' complete package plans for promising new programs, such as the Space Station."<sup>26</sup> Over the Christmas holidays Lucas visited William Brooksbank, who had experience with the orbital workshop, and convinced him to leave the Structures and Mechanics Laboratory to head Space Station work in Program Development.<sup>27</sup>

One of Lucas's first tasks was to assist the Center's executive staff in the preparation of a five-year institutional plan, an exercise mandated by NASA's Office of Manned Space Flight. For MSFC, the key issue was the "determination of Marshall's desired roles in the new programs (space station and lunar exploration)."<sup>28</sup> Lucas and the executive staff decided to make a bid for substantial Space Station work, including provision of Saturn launch vehicles; Station design, development and production; experiments in astronomy, technology, and manufacturing; integration of all experiments; and assistance work on a reusable logistic vehicle.<sup>29</sup> OMSF wanted a Station by 1975, and Marshall proposed that it could deliver with a budget peaking at \$199 million and manpower peaking at 1,000 Civil Service and 7,300 contractor employees in FY 1973.<sup>30</sup>

Before NASA could allocate Space Station assignments and move into Phase B program definition, a fundamental issue had to be resolved: should a Space Station provide artificial gravity? The issue divided MSC and Marshall. Von Braun and George Mueller, associate administrator for manned space flight, agreed that artificial gravity was unnecessary and inordinately expensive. Apollo

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manager George Low suggested that a Station ought to include both artificial gravity and zero gravity, but warned that “it would be extremely difficult, expensive and time-consuming to re-invent all that we have learned during the past century to obtain measurement instruments that would work in zero-G.” MSC Center Director Robert Gilruth, however, argued forcefully in favor of artificial gravity, and refused to accept a “zero ‘g’” station. Furthermore, Gilruth was reluctant to accept a compromise in which Phase B would consider both zero gravity and artificial gravity since he believed the strong advocacy of Mueller and von Braun would mean that artificial gravity would not receive fair consideration.<sup>31</sup> Von Braun retorted that while he was not opposed to artificial gravity, he was not in favor of making a major commitment to it “until we understand the phenomenon and its implications [including] technology, design, operational considerations, schedule, cost, and attraction of potential users.”<sup>32</sup>

Charles Mathews found a compromise that addressed Gilruth’s reservations. The 1975 station was to be the first step toward assembly of an enormous craft of assembled modules. If Paine wanted a bold plan, Gilruth offered him one in the form of a 100-man space base. NASA agreed to accept a space base (reduced to a 50-man crew) as a long-term goal, and agreed that it would have a classic wheel form with artificial gravity in the perimeter, and zero gravity in the hub. This concession allowed for the construction of an interim 12-man Space Station targeted for a 1975 launch.

Mathews’s compromise was so technologically complex, politically naive, and financially extravagant that it helped to kill Station prospects. It satisfied no one in the NASA community, and led to acrimonious meetings at Headquarters in January and February 1969. Marshall argued that the module should be integrated into the Station; Houston wanted it to be a prototype. Marshall still believed that the 1975 station should not require artificial gravity since experimenters wanted zero gravity, and suggested that Mathews was ignoring potential users. The Center in fact disagreed so strongly with Mathews that it presented an alternative plan a week later, but Gilruth and Mathews rejected the MSFC approach as having “too many pieces.” Gilruth and Lewis Director Abe Silverstein wanted to move directly to a large Station without an interim step.<sup>33</sup> Ultimately, politics rendered Mathews’s compromise unfeasible. The Nixon Administration told NASA to expect cuts.<sup>34</sup>

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Before Mathews adjourned his series of Headquarters-Center meetings, he directed the Centers to study module designs for the 1975 launch. Each Center would direct a contractor design study for a “common” module, so called because it could both serve as a building block for a space station and operate independently. By late April, Headquarters set base requirements: the module would have to be 33 feet in diameter, carry a crew of 12, and serve either a zero-or artificial-gravity space base. MSFC would then investigate zero gravity, MSC artificial gravity.<sup>35</sup>

While Mathews and the Centers were fashioning hubbed pie-in-the-sky plans, budget realities forced Mueller to make a choice between Shuttle and Station. But even while Mueller and NASA brass struggled to find a way to build both a Space Station and a Shuttle, the Centers continued their station planning.

Von Braun named Brooksbank to head Marshall’s Space Station task team, and Brooksbank established rapport with his Houston counterpart. Cooperation between the two teams showed not only that MSC and Marshall could work together, but that there were immediate advantages to doing so. “Rene Berglund and I were quite compatible, which was somewhat unusual between the two Centers,” Brooksbank recalled. “Both of us were mature, and we managed to get along very well.” Cooperation strengthened their hands at their respective Centers. “If we reached agreement fairly soon on most major issues, we were able to make our point of view stick within our own Centers which eliminated a great deal of friction.”<sup>36</sup>

Planning now began in earnest, as Marshall and Houston each directed \$2.9 million Space Station program definition studies. Working from identical statements of work, McDonnell Douglas conducted the Marshall study while North American worked for Houston. These Phase B studies aimed to design a 12-man Station to be launched in 1975, examine concepts for a 50-man space base to be operational in the late 1970s or early 1980s, and plan logistics systems to support the station and base.<sup>37</sup>

One of the conundrums facing NASA in its post-Apollo planning was to find a managerial approach that would preserve the strengths of the semi-autonomous field Centers and impose the centralized control needed for large national space programs. When Mathews assigned Frank Borman to the new post of field director and instructed him to chair a Space Station review group that would “integrate” the Phase B studies, von Braun feared intrusion on traditional

Center authority. He worried that the review group might undermine Center management and interfere with Center-contractor relations. "I would want to be assured that the review group does not provide direction to the Field Centers and especially not their contractors," he insisted.<sup>38</sup>

The field director's office never became as intrusive as von Braun feared, but Marshall worried about Headquarters micromanagement.<sup>39</sup> Program Development Director Lucas noted that "an inordinate amount of time has been spent in reporting," and added that "most of the extra reporting requirements have been generated by Headquarters."<sup>40</sup> When Washington warned new Marshall Center Director Eberhard Rees to give contractors maximum latitude in their Phase B Shuttle studies (see Chapter VIII), the warning had implications for Station. Brooksbank insisted that close contact with McDonnell Douglas was essential to the success of the Station, telling Rees that "MDAC and Marshall have established a total Space Station team to the mutual advantage of MSFC and NASA, and a Phase B study would be sterile within the written guidelines without this personal interplay."<sup>41</sup> Rees insisted that "our scheme of using working groups staffed by senior MSFC personnel allows efficient penetration without interference."<sup>42</sup> Cooperation between Brooksbank and JSC's Space Station task team leader Rene Berglund also prevented intrusion from Washington. "We found that Headquarters could not stand if the two of us agreed on something beforehand," Brooksbank recalled. "They always acquiesced to the approach we would take."<sup>43</sup>

### **In the Shadow of Shuttle**

Redefining the relationship between Headquarters and the Centers would be a continuing issue as the Space Station program evolved, but by 1970 it became a peripheral matter as NASA, industry, and the Nixon Administration entertained doubts as to whether Space Station was realistic. In the months following the Apollo moon landing, altered circumstances placed the program in jeopardy. Tight budgets, suspension of Saturn V production, the reluctance of Congress and the administration to endorse a plan encompassing both Shuttle and Station, and the realization that early plans had been too optimistic forced NASA to reconsider plans for a Space Station.<sup>44</sup>

In March 1970 President Nixon selected the Shuttle and Station as national goals, but deferred Space Station until after development of the Shuttle. During the next two years Marshall, MSC, and Headquarters struggled to redefine the

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Space Station program, first seeking to salvage as much as possible from the original Phase B studies in a new modular design, then trying to find ways simply to keep the program alive, and finally incorporating portions of the Space Station concept in other NASA programs.

The new environment forced NASA to adopt a fresh perspective on the Station, and four concepts drove design studies. The Station would use the Shuttle; early studies had relied on the Saturn. Station plans applied a conservative engineering approach; the Agency would build on Apollo and Apollo-derived technology (such as *Skylab*) rather than attempt to break new engineering barriers. The Station design would be evolutionary; most designs for the next decade planned to start simple and grow. Finally, the Space Station would involve international partners.

Grandiose plans for a space base thus gave way to in-house studies of a less expensive, more flexible modular Station with more flexibility. “When it became clear that the next program was going to be Shuttle,” William Huber of Marshall’s Program Development office remembered, “the first thing we did was a study activity of how we could modularize the space station into modules which would fit inside the Shuttle.” Studies out of Huber’s office examined ways to use the 15- by 60-foot modules “to accomplish the same objectives as the big one, but doing it in modules.” Clusters of modules could approximate the capability of Phase B plans, but also give NASA a fallback position in which a limited one-module facility could be launched by a single Shuttle. Modules offered other advantages: reduction of initial and total costs, ease of replacement, and the opportunity to return them to Earth for refurbishment. In June 1970, MSC and Marshall began 90-day in-house studies evaluating module options.<sup>45</sup>

JSC and Marshall Station plans diverged as the Centers sought ways to salvage the Station. The planning staff in Houston urged cancellation of the launch of a first Station element, now scheduled as part of a 1976 Bicentennial extravaganza, since the Station might damage NASA’s reputation either by delivering less than *Skylab* or by costing more than Congress could support. Houston considered more extensive revisions of earlier plans than Huntsville.<sup>46</sup>

The Space Station needed more than a new design if it was going to survive, however, and NASA tried to bolster public confidence. In September 1970, the Agency tried to create a Station constituency by sponsoring a meeting at Ames

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Research Center of engineers, scientists, aerospace corporation executives, academics, and government representatives from the United States and foreign nations. Even those who supported the concept of a space station doubted whether sufficient funding would be available. Others questioned the wisdom of proceeding since most work projected for a space station could be done on a Shuttle, and scientists questioned the need for another manned vehicle. Ernst Stuhlinger, one of Marshall's representatives at the meeting, concluded that scientists, engineers, and corporate leaders alike were "acutely aware of the discrepancy between our total program (station, shuttle, tug, nuclear stage, Viking, Grand Tour, astronomy, exploration of the moon, exploration of the solar system) and our dwindling resources."<sup>47</sup> If potential space station users doubted NASA's dreams of two new major programs, Congress, the administration, and the general public were even less supportive.

Uncertainty pervaded NASA's Station redesign efforts. After the Centers initiated in-house modular studies in the summer of 1970, they requested their contractors to examine modular concepts. After Marshall's Phase B contract with McDonnell Douglas and Houston's with North American Rockwell concluded early in 1971, the two Centers initiated new studies with their contractors (termed Phase B Extended) for a modular station that would be compatible with the Shuttle, acknowledging "the funding constraints imposed by current budget estimates."<sup>48</sup>

The new studies were barely underway before a new threat loomed. The Office of Management and Budget, reasoning that "the current and anticipated pace of the space program clearly indicates that space station activity would follow the shuttle by at least several years," directed that Space Station funding would be "constrained," and that current station funds be expended more for Shuttle-related programs (such as the Sortie Can) than for long-range Shuttle planning.<sup>49</sup> Now began a complex dance in which Marshall and MSC competed for management of NASA's major manned space flight programs of the next two decades, and in which Headquarters struggled to find appropriate managerial tools to direct the Agency in a dramatically altered post-Apollo environment. Each of the three parties—Marshall, MSC, and Headquarters—had much at stake. Each took many uncertain steps, and in the process raised questions that NASA would wrestle with for more than two decades.

Indications were that Houston would be Lead Center for the Shuttle. But that left numerous projects up for grabs, including Sortie Can, Space Station, nuclear

propulsion studies, payload studies, and Space Tug, as well as major elements of the Shuttle itself. It appeared that Space Station would be the next plum assignment. Competition was clouded by increasing awareness that the Agency would not be able to buy everything on the menu—or would at least have to order smaller portions, as was already the case in Space Station.

For Marshall, being decimated at the time by post-Apollo reductions-in-force, management of new projects offered opportunity to diversify. If Marshall was aggressive in pursuit of new projects, MSC was on the defensive. In May 1971, Associate Administrator Dale Myers recommended that MSC be assigned Lead Center on Shuttle.<sup>50</sup> With control of Shuttle within its grasp, MSC looked for ways to prevent Marshall from encroaching on its authority for operations, astronauts, and manned vehicles. But *Skylab* was clouding Center roles and missions, giving Marshall experience in all Houston specialties. Houston thus argued that its management of shuttle necessitated control of key interfaces, some of which would have precluded Marshall expansion.

Headquarters also found itself on uncertain terrain. In the aftermath of Apollo, Headquarters had to tread carefully between often-contradictory alternatives. Headquarters wanted to ensure that the Agency would have ample funds to support NASA programs, and could do so only by avoiding political problems and developing constituencies among aerospace contractors, researchers, and the public. Headquarters wanted to control Huntsville and Houston; but the engineering talent rested in the Centers and a Washington-based bureaucracy might destroy NASA's technical culture.

Part of the Headquarters' management approach was to balance Huntsville and Houston. When Myers recommended that MSC manage Shuttle, he suggested that any future work on RAMs (Research and Applications Modules, the forerunners of Spacelab) should be assigned to Marshall. Furthermore, Marshall would be designated Lead Center for Space Station at the conclusion of the Phase B studies. In July, a week after assigning Shuttle to Houston, Myers formally awarded Marshall integration responsibilities for RAM and Space Station, a task that entailed "definition, design, and verification of design concepts."<sup>51</sup> The last word in Station management decisions had not been said; in fact Myers had rendered only the initial paragraph of a long treatise.

Whether Marshall's assignment meant anything remained to be seen, since Space Station seemed to be performing a disappearing act. Congress would fund only

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one major space program, and Space Station became a dream deferred. Marshall's Space Station task team finished its contractual modular station studies in December 1971 and disbanded the following June.<sup>52</sup>

Marshall continued to conduct station-related studies under the auspices of a new Concept Verification Test (CVT) program, established to simulate environmental control and life support systems applicable to future manned systems. Brooksbank, Marshall's Space Station task team manager, directed CVT on the assumption that the limited funding available to Station in the mid-1970s could be applied in select critical areas, cutting costs and accelerating Space Station into Phase C/D.<sup>53</sup>

Lucas, now serving as Rees's technical deputy and thus the second-ranking administrator at Marshall, recognized the long-term benefits to the Center: "The attractive thing about all the elements of the prospective program is that, in addition to supporting a Space Station sometime in the distant future, the technical development will be very important to what lies between now and the Space Station, for example: RAM and Shuttle Cargo Bay. All the work we do will determine whether we obtain a Space Station or not." Support for CVT offered both technical and political advantages. "In some respects, we will be competing with MSC again," Lucas continued, "but I think we must do this to offer the strong capability in Spacecraft subsystems and systems design that we have developed in the *Skylab* program."<sup>54</sup>

CVT enabled Marshall to win Lead Center responsibility in June 1971 for an integrated Earth orbital systems effort in which the Agency kept Space Station planning alive, but it also led to contention with Houston. "After space station studies themselves were over [and] CVT was underway, we ran into some very, very confrontational politics between the two Centers," Brooksbank recalled.<sup>55</sup> Once again Marshall and MSC were moving on parallel paths, since Houston was developing a Space Station prototype (SSP) in a project contracted to Hamilton Standard. Both projects required the development of pressurized enclosures as preliminary steps toward Space Station development, and NASA could not afford duplication. Headquarters reduced Houston's funding and directed that Marshall provide the containers for testing, and instructed the Centers to coordinate their projects to ensure compatibility.<sup>56</sup> Cooperation between the Centers did not come easily, and on occasion Marshall had to request Headquarters give direction to Houston rather than work directly with MSC. Gilruth complained to Associate Administrator Myers about the incorporation

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of Houston's SSP and Environmental Control and Life Support System (ECLSS) into Marshall's CVT program, claiming that "planning has proceeded with a minimum of consultation with MSC" and with a "significant lack of understanding of the intended use of the hardware."<sup>57</sup>

"I don't believe the issue on our lead role in the CVT is now open," James Murphy, Marshall's director of Program Development, worried in November when Houston delayed delivery of SSP equipment to Huntsville. "I would not want to embarrass the Center by requesting delivery early just to enforce our lead Center role."<sup>58</sup> Indeed in late November 1971, Myers reaffirmed Marshall's role, insisting at the same time on closer cooperation between the Centers. "In terms of your role in CVT," he told Gilruth, "I envision MSC as a prime subcontractor for ECLSS, just as MSFC serves as a prime subcontractor to MSC for the Shuttle Booster."<sup>59</sup>

Development of life support systems was at the heart of the dispute and its resolution would affect later Space Station decisions. George Hopson, who had years of experience in the field, explained that it was clear very early that "probably the pacing technology for a space station would be the environmental control and life support systems." Other systems drew on earlier technology, "but on space station where there's several people living there for extended periods of time, everything that they use has to be resupplied. You don't have to do much calculation to see that one of the biggest problems is water and oxygen and the atmosphere that they breathe. . . . Most people, including myself, think that's the toughest job on the Space Station."<sup>60</sup>

Rees and Gilruth worked out an agreement which Headquarters accepted with slight modifications. The final decision retained some ambiguity; Marshall would control ECLSS, but Myers said he would "look to MSC as the lead Center in life support development" to recommend test objectives.<sup>61</sup> The solution took care of the short-term problem by giving both Centers jobs, but was no resolution; indeed it was the birth of a long running controversy over which Center should manage ECLSS.

In spite of intercenter competition, CVT kept Space Station studies going during shuttle development. "Every test we did in CVT for the first two years," Brooksbank insisted, was "directed and aimed at space-station problems." CVT examined some of the more challenging technological problems the Agency

expected to encounter when the Space Station program could be revived. “We took those technologies that were long tent poles in designing the stations,” Brooksbank explained, “and tried to implement them through the technology route.” High-density solar arrays, the Astromast used to deploy the arrays, and a high data-rate system were all incorporated into the CVT study.<sup>62</sup>

Marshall could not afford to devote much of its scarce resources to a distant dream, however. Rees worried that the CVT team was so involved in Space Station that it might jeopardize the Center’s efforts to secure related projects with a more immediate payback, and directed the group to broaden its focus.<sup>63</sup> Space Station consumed a declining portion of Center attention. Task team members found other assignments; Brooksbank became the deputy manager of Spacelab. For the time being, Marshall’s and NASA’s interest in building a Space Station remained alive mainly in related programs such as *Skylab*, Spacelab, and Shuttle.

### **New Strategies: Evolution Versus Revolution**

Although Space Station was but a footnote in NASA’s activities during the decade beginning in 1974, Marshall and JSC continued planning. The two Centers applied different philosophies as they worked on Station plans, with Marshall proposing evolutionary development of a station that could grow incrementally, and Houston urging commitment to a larger concept that could win program approval up front, an approach that NASA planners deemed “revolutionary.” Each Center pursued its plans demonstrating how intercenter competition could generate creativity.

NASA clung to the belief that Space Station would be the next logical step, the major new start after Shuttle. The Agency also had a general idea of what it wanted: a modular station that could be positioned in either geosynchronous, low inclination, or low-Earth orbit, and could serve both as an orbiting laboratory and a space construction base, service facility, or Shuttle depot.<sup>64</sup> The new baseline station of the mid-1970s was more modest than its predecessors: a four-person Station capable of being placed in orbit by two Shuttle flights, one of which would carry a subsystems module and a habitability module, the other a logistics module and a payload module. The arrangement would allow for expansion.<sup>65</sup>

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In 1974 the Agency began a series of Space Station studies, most of which were either managed by MSFC or parallel studies under Marshall and the Johnson Space Center. In August 1974, Marshall contracted a \$274,000 study for a nine month McDonnell Douglas study of a Manned Orbital Systems Concept (MOSC), a permanent orbital station. The MOSC study was “probably the most fundamental study of that period in the ‘70s,” according to Robert A. Freitag, NASA’s deputy director of Advanced Programs, since “it really got us into the serious Space Station activity.”<sup>66</sup> The study concluded that a MOSC facility could deliver more man-hours of space study at a lower cost than comparable Shuttle-launched Spacelab missions could provide.

The following summer Marshall, Johnson, and Kennedy formed a joint action group to devise an option for a geosynchronous space station.<sup>67</sup> In March 1976 Marshall and JSC negotiated \$750,000 contracts for Space Station systems analysis with Grumman and McDonnell Douglas, respectively.<sup>68</sup>

With space station planning accelerating, Marshall reestablished a Space Station task team within the Program Development Directorate in the same month that the Center initiated the Grumman contract. Lucas named Huber as manager, and directed the team to analyze Station systems and configuration options.<sup>69</sup>

While the mid-1970s studies helped NASA refine the type of station it wanted, the Agency also sought convincing arguments to explain why it wanted to build a station. NASA was committed to a space station, but Congress, the public, and the White House had to be convinced that the expenditures for another major space program in a new “era of limits” was worthwhile. At a management meeting in March 1976, Freitag asked representatives of the Centers and Headquarters to list 20 reasons for a station in “compact, pithy language.” Everyone could compile a list, but Jerry Craig, manager of one of JSC’s Station studies, summarized NASA’s promotion problem: “I think we must recognize that in virtually every objective considered singly, you cannot present an absolute argument for a permanent space station as opposed to multiple Shuttle flights.”<sup>70</sup>

Recommendations for potential uses of a space station posed a dilemma. Bob Marshall remembered that the three basic proposals for using station were not compatible:

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“First, science for viewing the universe and studying earth are generally compatible except for the direction for viewing. Second, materials science has been a user and desires maximum zero gravity conditions. Thus, any movement of men or repositioning interferes with processes requirements. Third, a refueling station for vehicles planned for deep space and planetary exploration would require frequent traffic with attendant disturbances and very hazardous operations.”<sup>71</sup>

Freitag, however, had his own idea of the purpose of a space station, and during 1976 began to promote “space industrialization” as a goal, sparking a shift from the traditional concept of a station as an orbiting scientific laboratory. Freitag suggested material processing, construction of communications antennae, use of solar energy, and Earth observations as worthy topics for space station studies, and advocated employing a space station as a space construction base.<sup>72</sup>

With the new MSFC task team beginning operation, Freitag’s approach provided grist for Marshall’s mill. In 1976 alone, the Center solicited proposals for space industrialization studies, managed a Grumman Space Construction Base study, and included space construction and processing scenarios in a July in-house station definition. Marshall’s Program Development office proposed that early shuttle flights include demonstrations in assembly of large space structures.<sup>73</sup>

Problems in winning support for a new Space Station program influenced NASA’s development approach. The Agency debated whether to build the Station incrementally, or seek approval of a large program comparable to Apollo or shuttle. “Our thought was we get to Space Station by a series of well-planned steps, a few steps at a time,” Huber explained. “The other theory is that NASA progresses in these momentous presidential decisions—Apollo, Shuttle, Space Station. Multi-billion-dollar steps.”<sup>74</sup>

“The Marshall approach back in the seventies and the early eighties was build something that the country can afford,” said Cecil Gregg, who worked on several of Marshall’s concepts during the period. “Then expand from that.”<sup>75</sup> The Center was convinced that “smaller is better,” and pushed the idea of modular stations launched by the Shuttle. “Bill Lucas referred to the MSFC approach as a colony of stations in orbit,” Bob Marshall remembered. “Through a

modularization of elements, three or more separate stations could be built at an equal or lower cost.”<sup>76</sup>

Once again Huntsville and Houston were on opposite sides of the question. “The folks at JSC said they felt they would like to have permission to take a look at doing [something] really big,” remembered William Snoddy of Program Development. “Wham. Here it is, all in one chunk. It was referred to by some of us as the revolutionary space station. It didn’t evolve; it was white-paper brand new. . . . We were trying to be more cautious, and they were proposing the big thing.”<sup>77</sup>

Unlike the CVT dispute in which Marshall and JSC wrestled for control of a study project, the debate over the Space Station development approach showed how NASA intended to employ intercenter competition to unleash the creativity of both Centers. Each Center developed plans independently, giving NASA a chance to evaluate two viable options. JSC proposed a Space Operations Center (SOC) that Center Director Chris Kraft described as “a permanent manned facility in low earth orbit, dedicated to the development and use of space construction techniques, and to the servicing of space vehicles including assembly, launch servicing, refueling, and re-use.”<sup>78</sup> It would employ two each of three different types of modules—service, cargo, and habitability—positioned along solar arrays that would span 433 feet. The SOC thus would be devoted primarily to operations, while most station proposals had concentrated on scientific purposes.<sup>79</sup> “We really never believed that was the way we wanted to go,” explained Gregg, who helped develop Marshall’s alternative. “We felt the science station . . . was the right way to go, not to try to move the whole mission operations and mission control function to orbit.”<sup>80</sup>

Marshall’s evolutionary approach centered on establishing a platform or module in space that could be used as a building block. Center engineers suggested in 1977 that either a Shuttle external tank or a Spacelab module could be employed in such a fashion.<sup>81</sup> Headquarters was more interested in another Marshall proposal, a 25-kilowatt power module designed to extend the Shuttle’s time in orbit by providing additional power. The Office of Space Flight told Marshall to plan for a \$90 million hardware development effort, and in March 1979 the Center established a project office under Luther Powell to direct development.<sup>82</sup> It was “just a big power supply in the sky,” according to Snoddy. “When you went up with a Spacelab mission in the back of the orbiter you could plug into

this thing, get more energy for the experiments, and also more energy for the orbiter; thus you could extend its lifetime on orbit for another week or two.”<sup>83</sup>

Extra time in orbit was an important selling point for the power module, since the short 7-day duration of Shuttle flights fell short of the 89-day *Skylab* mission. “The science community began to realize what was there,” recalled Powell. “Quite a few of them were enamored with the idea that here’s a rich power supply in orbit.” Scientists could “put experiments onboard and they can stay there forever and can be changed out by the astronaut crew.”<sup>84</sup> Scientists in NASA also recognized the potential provided by the 25-kilowatt power module. Andrew J. Stofan, deputy associate administrator for space science, suggested that shuttle flight durations of 20 days might be possible by using the module, perhaps in combination with a JSC-sponsored power extension package (PEP) aboard the Shuttle. Stofan even suggested that combinations of platforms, Spacelabs, and power modules might allow flight durations of as much as 60 days.<sup>85</sup>

Marshall explored other platform concepts, any one of which could have provided an initial building block for a space station. In 1979 the Center initiated studies of a Science and Applications Space Platform (SASP) and a geostationary platform.<sup>86</sup> The Center sponsored a workshop on space platforms early in 1981, sharing its ideas with representatives of federal agencies, the aerospace industry, and space communications companies. By now engineers envisioned the 25-kilowatt power module as the foundation of an incremental manned space platform system. The addition of extension arms could transform the module into an SASP. By adding more modules later, the complex could be enhanced to host crews of eight or more astronauts.<sup>87</sup>

### **Planning From Headquarters**

Soon after his inauguration, President Ronald Reagan nominated James Beggs as NASA Administrator and former Secretary of the Air Force Hans Mark as his deputy. Beggs, a NASA veteran who had been working in private industry, believed that a space station was “the next logical step” for the Agency.

Indeed the change of leadership in the White House and at NASA Headquarters offered opportunity to reinvigorate the Space Station program. The Carter Administration had not been enthusiastic about space programs, and never

considered a major new start for a space station. Administrator Robert Frosch had all he could handle trying to keep shuttle development apace. Many in NASA, and particularly those involved in space station studies, viewed Beggs's arrival as an opportunity for a fresh start. After years of trying to "keep the system alive," according to Powell, "we felt like all that we had done to keep that embryo breathing paid off for us."<sup>88</sup>

The change also gave Headquarters opportunity to assert control over Space Station. From the early studies of the 1960s into the 1990s, NASA wrestled with the question of whether Space Station should be managed by Headquarters or by its development centers. Indeed Apollo and Shuttle witnessed experiments in organization, but Space Station demonstrated the Agency's ambivalence in unusual ways; for the first time the Agency vacillated between Headquarters management and relative center autonomy within one program.

At the time of Beggs's confirmation in June 1981, Marshall and JSC station studies offered options ranging from the JSC Space Operations Center to the MSFC evolutionary platforms based on the 25-kilowatt power system. Marshall tried to convince the incoming NASA leadership of the viability of its approach, and seemed to win support. Bob Marshall presented Huntsville's evolutionary approach to major contractors and to Headquarters, and received a favorable response. Headquarters directed JSC to assess using the MSFC power system and Spacelab as the foundation for an initial station.<sup>89</sup> MSFC Center Director Lucas explained the Marshall position to Mark shortly before Mark's confirmation, insisting that the Center still believed it was the best way to go. "That is the only way to go," Mark responded.<sup>90</sup>

Beggs agreed, and often insisted that he wanted to buy the space station "by the yard." What that meant would become clearer as Beggs sought presidential approval for a space station in the two and a half years that followed, but it implied both the evolutionary development approach favored by Marshall and the process of winning approval described by political scientist Howard McCurdy as "incremental politics."<sup>91</sup> In November, Beggs appointed Philip E. Culbertson as associate deputy administrator and directed him to manage planning for Station. John Hodge, another NASA veteran who had left the Agency, and Freitag joined Culbertson's staff.<sup>92</sup>

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Freitag drew up a charter for a Space Station task group to coordinate Station planning out of Headquarters. “The reason I did this,” Freitag explained, was that “when we had set up the competition between Marshall and Houston to look at both sides of it we were overly successful and we had set up a dichotomy that was disastrous. They were absolutely destroying each other.” Freitag hoped to “wipe out all vestiges of the inter-center rivalry,” even if it would take six months or a year. He believed that the only way to proceed was to cancel out Center projects like Marshall’s platforms and power modules and Houston’s Space Operations Center, and “bring everything into Headquarters.”<sup>93</sup>

General James Abrahamson, associate administrator for Space Transportation Systems, who was organizing NASA’s Space Station definition effort for Beggs, pulled funds from the Center Station study budgets to initiate contractor mission studies and “waived off” JSC and MSFC objections.<sup>94</sup>

Marshall objected to commissioning more contractor studies.<sup>95</sup> The Center wanted NASA to begin development of a space platform and conduct Phase B studies of a habitable module, an approach consistent with the Center’s commitment to evolutionary development of station. Jack Lee received assurance from Headquarters that Beggs still favored Marshall’s platform approach, and that he would seek approval for a start in 1984.<sup>96</sup> MSFC Program Development Director Bob Marshall argued that hardware under development would mean more to the Agency than more requirements studies, since once development began and metal was bent programs are seldom canceled.<sup>97</sup> Abrahamson was adamant, however, and soon announced plans to proceed with several contractor studies.<sup>98</sup> Furthermore, politics made an evolutionary station unlikely. Hans Mark was convinced that station would be a decision made at the top; there would be no “tolerant or permissive” attitude that might permit a low-cost evolutionary approach.<sup>99</sup>

Conceding that the mission studies (comparable to Phase A) would be directed out of Washington, JSC and Marshall positioned themselves for pieces of the development pie. The opening round of negotiations offered a split similar to the Shuttle/Spacelab division of responsibilities. Bob Marshall suggested to his Houston counterpart Joe Loftus that they begin program negotiations. He planned to seek MSFC management of the platform, platform orbital operations, payload modules, and payload interfaces, and conceded the habitability module, airlock, Station operations, Shuttle interfaces, and crew training to Houston.

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This would leave Level II (Lead Center) responsibilities, the logistics module and the multiple docking assembly open for negotiations.<sup>100</sup> Unfortunately the discussion did not result in an agreement; by the time the two Centers would meet again to divide responsibilities, politics had intervened and a simple division of labor was no longer possible. Moreover, Headquarters was not about to turn responsibility over to the Centers at this point, and friction between the Centers and Headquarters was apparent. At one meeting, Houston's Loftus noted that "there were numerous references to 'the conservative Centers' (MSFC and JSC) and generally a negative attitude toward Center capabilities."<sup>101</sup>

Beggs announced establishment of the Space Station task group under Hodge's direction on 20 May 1982. The task group was to build a constituency for a Space Station and define a concept that might win approval for a new start for NASA. To do so, it would have to determine mission requirements, architectural options, and approaches for advanced development, systems engineering, management, and procurement. A loosely structured committee, the task group conducted most of its work through working groups whose conclusions would be reviewed by a program review committee chaired by Freitag.<sup>102</sup>

Hodge and Freitag had accomplished two goals even before the working groups began meeting. First, the establishment of the task group transferred Space Station impetus from the Centers to Headquarters. Second, by careful selection of the membership and leaders of the working groups, they spread Station work among the Centers to ensure that no one Center would dominate deliberations. The balanced workload minimized NASA's internal disputes at a time when the Agency needed to speak with one voice in order to combat external opposition to Space Station. It also fostered long-term problems, however, since the Centers insisted on a favorable division of the development spoils.

Headquarters did not establish all working groups at the same time it announced formation of the Space Station task group, and in fact it took nearly a year before all working groups were in place. Rumors circulated during the interim as the Centers worried about their stake in the station. As early as September 1982, members of the task force believed that Headquarters had decided to award Lead Center responsibilities to JSC, but Terry Finn of the Headquarters staff warned that Marshall should not be cut out or NASA could lose the support of the Alabama congressional delegation.<sup>103</sup>

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Headquarters encouraged JSC and Marshall to submit proposals for Station management, and each Center made a pitch for Lead Center duties. JSC cited Apollo and Shuttle spacecraft experience. Marshall pointed to Saturn, *Skylab*, and Spacelab. The Marshall document argued that the Center was “characterized by total systems management of hardware development, high program visibility, effective program control, technical penetration, fast response, organization flexibility, and established interface with the User Community” (emphasis in original), and that the Center had a “sound success record in complex hardware performance management.”<sup>104</sup>

Still, rumors of JSC’s selection persisted, and Marshall managers worried early in 1983 that Hans Mark and JSC Director Jerry Griffin had struck a deal that would designate Houston Lead Center. “The tone and discussion in the halls of Washington is that MSFC is going to be eliminated from the space station competition,” Bob Marshall, MSFC Director of Program Development, cautioned Lucas. “It is frequently stated that it is Johnson’s position that they want to eliminate all competition,” he continued, “and in attaining the assignment would totally operate the program from JSC.”<sup>105</sup>

Bob Marshall also worried that Powell had been eliminated from consideration for a post in Washington, but Hodge chose Powell to head the Concept Development Group (CDG). The CDG, formed in April 1983, was one of the two most important working groups—the other being the Program Planning Working Group (PPWG), created in September 1982, and chaired by Craig at JSC.<sup>106</sup> NASA’s planning under the task force aimed to win support for Space Station from broad constituencies. Concurrent with the establishment of the CDG, FY 1984 budget decisions curtailed further industry participation in Space Station planning. Beggs shifted NASA’s effort to “an in-house effort concentrating on technology and systems engineering.”<sup>107</sup> To close out contractor studies then underway, he ordered a series of briefings in which the companies explained their Station studies to the Agency and to the Defense Department, which had been reluctant to commit its support to a space station.<sup>108</sup> The briefings, held at Marshall in April 1983, gave the CDG a base on which to build its concept studies.<sup>109</sup>

Powell went to Washington in April 1983 on loan from Marshall and set up shop below the cafeteria in a warehouse built in the 1930s, the only quarters NASA could find in the capital. The building leaked so badly that a 50-gallon

barrel filled with water each day, and in the winter frozen pipes burst. The NASA inspector general ordered the team out after discovering a sewer leak, but no other quarters could be found and the group continued to work out of the same location.<sup>110</sup>

By June the CDG had a full staff. When Beggs told Powell that he wanted to buy the Station “by the yard,” Powell replied, “I want to first show you what the bolt’s got to look like that you buy the first yard from.” Describing the bolt became the CDG’s task. To do so, Powell’s group drew on trade studies, and sought input from interested agencies including the Department of Defense and the State Department. Powell had a small budget, but found a way to get aerospace firms to contribute without letting expensive contracts. Several firms wanted to work with the CDG. Powell offered them a deal: they could take part in discussions and receive copies of the reports of other participants if they would contribute reports of their own. Many agreed, and review meetings of the CDG often had more than 100 people in attendance.<sup>111</sup>

The CDG also helped set NASA’s initial budget proposal, the figure on which President Reagan based his decision to support the Space Station. Shortly after taking office, Beggs asked former Administrator Fletcher to chair a panel that would estimate the development cost of an initial Station. Fletcher doubted that Congress would approve more than \$1.5 to \$2 billion, and decided to recommend a minimum figure in that range. Beggs was more confident that he could sell the program, and worried that the estimate might be unrealistically low. He asked Powell and the CDG for an independent estimate. Powell and his team knew the \$2 billion figure was far too low. They suggested that costs could be kept down by using a common module that would eliminate duplication costs that would accrue with independent design. Powell drew a wide curve with an upper limit of \$9 billion and a lower limit of \$7 billion.

“I took it to Beggs, and he sat there at his table and looked at it for the longest time and grunted three or four times, and I walked him through the whole thing,” Powell remembered. “I could see he was making up his mind. And finally, he just pointed to one and said, ‘I’ll take that one right there.’ It was the \$8 billion one, which was right in the middle between the seven and nine. So, I said, ‘Fine.’ He said, ‘Go get me some more details, and go work that out and come back and tell me.’”<sup>112</sup>

The \$8 billion figure caused problems. Beggs used it in an effort to propose a station that would be able to win presidential and congressional approval, but it was developed at a time when the Agency had insufficient information on which to base a realistic estimate and left the Agency committed to a baseline price that it could not deliver. NASA had lived on cost overruns before, but times had changed since the development of Apollo and Shuttle: Washington was more cost-conscious, the public no longer considered NASA's programs above review, and the changing international climate and tepid Defense Department support for Station diminished NASA's ability to justify the program as essential for national security.

### **Organizing Management**

During the summer and early fall of 1983, NASA held a series of internal meetings that increased the involvement of the Centers in Station planning. Three management decisions were at stake: Would Headquarters or a Lead Center manage Space Station? Would the Centers or contractors handle systems engineering and integration? How would the Centers divide development work?<sup>113</sup> Answers to these questions determined the contours of the Space Station program, establishing relationships among the Centers and between the Centers and Headquarters that triggered problems.

In July the Space Station task force briefed the Center Directors on its progress. The group had defined a space station design employing a cluster concept, with a manned base comprised of habitat, utility, and operations modules, with provision for the addition of growth elements (such as experiment and logistics modules), unmanned platforms, and an orbital transfer vehicle.

NASA now turned to management issues. In August and September NASA held a two-session Space Station Management Colloquium at which the highest levels of Center and Headquarters administration confronted Station management issues. Headquarters intended the first meeting, held at Wallops Flight Facility from 29 August through 1 September, to assess program management. By now years of planning had taken place, and Space Station had yet to win approval; Center representatives showed frustration at the endless tedium of meetings with no certainty that they would ever bend metal. One Marshall manager who took extensive notes revealed his frustration, writing: "I cannot understand the position of the government. They are all powerful to be

impotent, resolved to be irresolute, rabid for fluidity and adamant for drift. All the while the locusts eat.”<sup>114</sup>

The undertone of rebellion suggested in the above comments affected discussions. Level B program management emerged as a dominant issue, and the Centers agreed that it should be at a field Center, not at Headquarters. The Centers also differed with Headquarters over who should manage systems engineering and integration (SE&I) during design and development. Headquarters, and especially Hodge, believed contractors should do it; the Centers believed the work should be done in-house. Marshall had long advocated in-house systems work, and wanted the job.<sup>115</sup>

Having experienced the problems associated with management of NASA programs throughout their careers, the participants enumerated the dangers to avoid. Handwritten notes from one of the task meetings documented dangers in an insightful, even hauntingly prescient listing:

- 1) Lack of program definition early in program
- 2) Lack of clear assignment of responsibilities between Centers and between Centers and Headquarters (HQ)
- 3) Low balling by contractors and by NASA
- 4) Incompetent staffing particularly in the program M[anager]
- 5) Complex interfaces, hardware and organizational
- 6) Lack of attention to details by NASA during development (contractor penetration)
- 7) Contractor selection
- 8) Lack of understanding between field Centers and HQ on the Center commitment
- 9) Establishing program cost as the most significant driver.<sup>116</sup>

The conclusions of the Wallops meeting influenced the agenda when Center Directors, the Space Station task force, and other management personnel met at Langley on 22 and 23 September. The Lead Center issue dominated discussions. Headquarters had reservations about using a Lead Center; on other programs the approach had caused problems regarding control of resources, diffusion of responsibility, and intercenter rivalry. The Center Directors, however, were united in favor of using a Lead Center on Station, and reminded Headquarters that “Centers can, and do today, ‘work for’ another Center.” They

also agreed that the Level B (lead) Center ought to have control of the money distributed to Level C Centers. The message was clear: the Center directors were so opposed to Headquarters program management that they were willing to take a vow of intercenter cooperation.

As a consensus formed in favor of adopting the Lead Center concept, discussion focused on which Center should assume the responsibility. Langley received consideration from those who believed Level B should not be located at one of the development Centers, but soon dropped out of the picture. Lewis and Goddard chose not to seek the assignment, and KSC and Ames never considered it. That left Marshall and Johnson to compete once again. As NASA's most diverse Center, Marshall was competing with several Centers on other programs: with Goddard on space science and astronomy, and with Lewis on space station power. This worked to Houston Center Director Griffin's advantage when he lobbied to form a coalition in favor of JSC. At the Langley meeting, General Abrahamson called for an informal nonbinding straw vote on which Center should take the lead. With Lucas abstaining, Marshall received only one vote. Not everyone at Marshall wanted the Lead Center role. Bob Marshall, director of Program Development, believed the Center should try to get it, but both Powell and James Kingsbury had reservations. "I quite frankly think that the Center has been a hardware Center since day one and that's our forte, and we ought to stay with that," Powell remembered telling Lucas. "The only thing we have to recognize in lead Center is that you're going to do everybody else's dirty laundry. . . . Everything that goes wrong, it's going to be your problem."<sup>117</sup>

Before the actual division of program assignments took place, Center directors agreed on certain management principles. They insisted that clarity was crucial for the program to succeed: clarity of definition, purpose, schedule, and money. "Don't even suggest a purpose is 'save NASA as an institution,'" they recommended. They suggested that systems engineering and integration should properly be the role of the Government.

The Langley meeting addressed NASA's major Space Station management issues but did not resolve them. In the aftermath of Langley, managers at the Centers worried about the disagreement between Marshall and JSC. Operating on the premise that agreement could come if both Centers had a meaningful part of Station and other Centers received a responsibility that fit their role, they weighed options for ways to divide major elements (habitat, air lock, support module, logistics).

By the end of 1983, the Centers and Headquarters had come to agree on three assumptions that would guide planning. Systems engineering and integration would be done in-house. The Agency would avoid committing station to one prime contractor over the life of the program. And development would be spread among several Centers to help revive the engineering capability of the Agency.<sup>118</sup>

### **Presidential Approval**

The Space Station faced a critical juncture in the fall of 1983. NASA had devoted years to in-house and contractor requirements studies, conducted configuration and preliminary design reviews, and debated management options, but had yet to win presidential or congressional approval. President Reagan seemed supportive, but had backed off before when NASA thought it had won his blessing. Now Beggs and Hans Mark lobbied hard, and NASA gave a key presentation to the President during the closing days of the successful Spacelab 1 mission. But the Agency faced strong opposition from Congress and from within the administration. Budget Director David Stockman and Secretary of Defense Caspar Weinberger were vocal opponents. Beggs canvassed the Center directors to ensure that no hidden obstacles might undermine his campaign. Marshall's Lucas pinpointed NASA's conundrum: the Agency understood the technical issues, but could not demonstrate "an indisputable need and/or economical benefit." NASA needed political backing from the White House to proceed.<sup>119</sup>

Despite vigorous lobbying by opponents, the executive decision came in the State of the Union address on 25 January 1984, when President Reagan announced: "Tonight, I am directing NASA to develop a permanently-manned Space Station and to do it within a decade." Lucas welcomed the announcement of "an exciting new venture to which we in the Marshall Space Flight Center have looked for many years."<sup>120</sup>

### **Dividing the Pie**

NASA had been planning for a space station for years, and now had presidential backing. The Agency now took on its most difficult managerial task: dividing space station work between the Centers. Two choices made in the six months following the presidential blessing created problems that plagued the program for the next decade. For political reasons NASA assigned work packages to

four Centers rather than to the two major development Centers. Then NASA divided work by functional systems rather than hardware elements. These decisions multiplied interfaces into a maze of interrelated overlapping responsibilities.

Three weeks after Reagan's dramatic announcement, Headquarters decreed that JSC would be the Lead Center for Space Station. With Level B authority, Houston had responsibility for systems engineering and integration, business management, operations, integration, customer integration, and Level A (Headquarters program office) support.<sup>121</sup>

Although not unexpected, the announcement was a great disappointment to Huntsville. Bob Marshall was blunt: "We're not very pleased with not being named as lead Center." Hans Mark did little to cushion the blow when he said that Marshall had never been in the running, although he added that the Center would be "deeply involved" in Station work. Alabama Senator Howell Heflin demanded to know what Marshall's role would be.<sup>122</sup> It was a question that would take months of bitter wrangling to answer.

Center rivalry affected how NASA divided tasks on Space Station. Marshall was in the middle of the controversy, competing with Lewis Research Center and JSC. The first division concerned what NASA called the Space Station Advanced Development/Test Bed assignments, which involved the development by intercenter teams of technologies for specific space station applications. Theoretically, the advanced development tasks provided a means for research Centers (Langley, Lewis, and Ames) to contribute to space station technology development by working on teams with the development Centers (JSC and Marshall). NASA identified seven areas for advanced technology research, and in February assigned teams and Lead Centers. Three lead assignments went to Marshall (Attitude Control and Stabilization System, Auxiliary Propulsion System, and Space Operations Mechanism) and three to Houston (Data Management System, Environmental Control and Life Support System, and Thermal Management System). For the seventh discipline, Electrical Power, Headquarters assigned Marshall, JSC, and Lewis to the team, but deferred designation of a Lead Center. In each case, a team of personnel from other Centers supported the lead, so most Centers had a role in several advanced development tasks.<sup>123</sup>

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Both Marshall and the Lewis Research Center in Cleveland wanted the lead in electrical power, and Marshall's Lucas and Lewis's Stofan lobbied to win the assignment. The Ohio congressional delegation swung its weight behind the Lewis bid. Some congressmen threatened to withhold support for Station unless Lewis won an acceptable portion of work. Deferral of the decision on the lead for the seventh advanced development task complicated negotiations for work packages in the months that followed.<sup>124</sup>

For the Centers, division of work packages was one of the most critical of all Space Station decisions, for it would determine their share of work on NASA's major program for the next decade, perhaps longer. During management meetings in August and September 1983, NASA had decided to divide Station assignments on the basis of work packages that would structure Phase B procurement and determine Center responsibilities for Phase C/D development. Negotiations would be driven by both political and technical considerations, and both were complicated. Politically, NASA had made broad promises to diverse constituencies in order to win approval for Space Station, and not the least of these was a pledge to involve all eight Centers. Guidelines dictated that no one Center would "own 'it' all," and that no one Center would be overloaded. But beyond that, NASA had to determine the number of work packages, the level of participation by each Center, and the types of work packages.<sup>125</sup> Such vague guidelines allowed for endless permutations. Everyone assumed that JSC and Marshall would have major portions, and that Goddard would have responsibility in some way for unmanned systems. Culbertson was worried that too many work packages would unnecessarily complicate an already complex system, but contention over the electrical power advanced development task brought Lewis into the picture, and Stofan insisted that the Cleveland Center ought to have one of the work packages.<sup>126</sup>

Technical considerations were no less complex. The station configuration was not yet set; a skunk works at JSC would develop a reference configuration concurrent with work package negotiations, but it had not even met when the Agency began to consider the division of labor. NASA had decided to keep systems engineering and integration in-house, but had yet to determine whether it should be done by Level B or delegated to the Level C work package Centers.<sup>127</sup> The Agency hoped to keep work package assignments consistent with Center strengths, but even this criteria was ambiguous. Houston established expertise in habitation modules during Apollo and Shuttle, for example,

but Marshall's work in *Skylab* and Spacelab gave MSFC an equal claim to expertise.

At a meeting in Houston on 23 March, Headquarters assigned JSC Director Griffin the task of recommending a work package split.<sup>128</sup> Over the next two months Griffin engaged in what he later called "shuttle diplomacy" in an effort to reach agreement with other Center directors.

Unfortunately Headquarters had made a key decision that made Griffin's task formidable. Headquarters decisions dictated four work packages; the decision to give Lewis the electrical power advanced development assignment virtually guaranteed Lewis a work package in the same discipline, and Goddard's role in unmanned elements (platforms, free flyers and associated hardware) also fell into place. "Once that decision was made it forced us into splitting up the Station to the point where now it was difficult to have system control," Lee explained. Assignments for JSC and Marshall became much more complex as a result of the Lewis work package. Referring to the meetings in August and September 1983, Lee argued that "Some of us thought that we'd already had an arrangement between us and JSC on how that was going to be split, and we were ready to go with it." The Lewis assignment, however, "destroyed our little plan."<sup>129</sup>

The decision to grant Lewis a work package was political, a concession to the Ohio congressional delegation. The decision had inestimable consequences. It changed NASA's traditional *modus operandi* by having research Centers do development on major manned space projects. It cast into doubt the division of work between the Centers, destroying an understanding between JSC and Marshall, fostering greater (and unnecessary) Center rivalry. It led indirectly to Culbertson's decision to assign work packages to Marshall and Houston that reversed traditional Center strengths. It added complexity to an already complicated program. It made communications more difficult by adding additional prime contractors. It made distributive systems more difficult to manage by adding additional parties that had to be informed and agree to changes. In short, it may even have been the single greatest mistake in the program.

Now the split between Marshall and JSC would be more difficult, in part because of overlapping expertise, in part because of a tacit understanding that the workload should be equitably divided between the Centers. At a meeting of

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Center directors late in March, Hodge suggested that it was time for “a bunch of good old boys to sit around the table and split up the pie,” according to the notes of one of the participants.<sup>130</sup> Griffin, Lucas, JSC’s newly appointed Space Station Program Manager Neil Hutchinson, and other key personnel from each Center met several times in April and May. At the first meeting in Huntsville in April, they attempted to divide work based on equal money, but the approach proved unworkable. Powell remembered one Griffin visit to Huntsville when the two Centers came tantalizingly close to agreement:

“That time, that night, to give you an example of how it shifted, Marshall was going to take on the systems integration responsibility. JSC agreed to it. . . . They were going to have the ECLSS system, and they were going to have the crew system. We were going to have the structures and propulsion. They were going to have communications. We had it all pretty well worked out. As we walked away that night, everybody was extremely happy. They thought we got this thing made. And so next morning about 9 o’clock Neil Hutchinson called me and says, ‘Boy Luther, I really feel good about this thing—we’ve really made a tremendous accomplishment.’ And about noon Jerry Griffin called Lucas and said, ‘I’m sorry, I can’t agree to that—all bets are off.’ Then Neil Hutchinson called me and told me, ‘Yeah, they couldn’t agree with it.’ I never understood why.”<sup>131</sup>

Ultimately Griffin was unable to find a split satisfactory to both Centers, and at the end of May he reported to Headquarters that “Our areas of disagreement are significant and, I believe, are based on honest differences of opinion as to how the program should be structured.” He explained that discussions “lacked a crispness” because they proceeded parallel to the evolution of the program, a fact that “added considerable difficulty” to negotiations.<sup>132</sup>

It remained for Headquarters to arbitrate. The aspect of Griffin’s proposal that most troubled Hodge, now the acting deputy director of the Space Station program, was that the systems engineering and integration function would not be conducted by Level B in Houston, but rather distributed to the Level C Centers.<sup>133</sup> Indeed the means to handle systems integration would prove a formidable challenge.

In June, Culbertson, acting director of the Interim Space Station Program Office, asked Langley’s Director Don Hearsh to assist in working out a solution. Hearsh

and Culbertson met with Marshall officials on 11 June, and Hearth laid out principles to guide the split: strong Level B management, simple interfaces between Level B and the Level C Centers, commonality should be carefully contained and not foul up Center assignments, and an admonition that money should not be the driver in work package divisions. Lucas concurred with Hearth's suggestions.<sup>134</sup>

Culbertson then presented the Center directors two options; both had identical packages for Goddard and Lewis, and differed only in the JSC and MSFC assignments. The two options differed in that "Alternate A" assigned the assembly structure to Marshall's Work Package 1 (WP-1) and the common module to JSC's Work Package 2 (WP-2), and "Alternate B" reversed them.<sup>135</sup> After examining the proposal, Marshall argued that Alternate B provided "the worst mismatch of Center strengths and tasks," and that it threatened "such a profound impact on the total Agency, the contractors, and the development phase" and that as such "it should be rejected by all."<sup>136</sup>

The work package Center directors met with Culbertson and Hutchinson on 22 June. Noel Hinnners of Goddard and Stofan favored Alternate B. The two JSC representatives, Hutchinson and Griffin, "waffled" according to Lucas's notes, but leaned toward Alternate A. Lucas said that he believed Alternate B "made no sense," but that Marshall "could do all or any part."<sup>137</sup>

Despite Lucas's reservations, Culbertson made the split similar to his Alternate B proposal; the most important deviation was that Marshall, rather than JSC, would be responsible for ECLSS. Although most in the Agency looked to Houston for expertise in life support systems, Marshall could make a strong claim. "JSC had never built an environmental control life support system that was closed-loop," Powell pointed out. "The only thing they had ever built and flown was the lithium-hydroxide canisters as filters; but we built and flew *Skylab*, which had the mol[ecular] sieve, which has the nearest thing to a closed-loop that you can get."<sup>138</sup> "We were very pleased that we got the ECLSS responsibility at this Center," said Randy Humphries, who had worked on ECLSS in Spacelab. But he admitted that the decision "really surprised us. . . . The way they wanted to manage this thing drove what kind of discipline responsibility they assigned to the Centers."<sup>139</sup>

The distinction between Marshall and Johnson roles and missions was now indeed muddy. Marshall's work package included ECLSS, but Houston had the ECLSS advanced development task; JSC's work package included the Attitude Control and Stabilization System, for which MSFC had advanced development lead. Culbertson's reasoning was that JSC, as Lead Center, ought to be responsible for the Station's structure, even though this was an MSFC strength. His work package division flowed from this logic, and thus deviated from the assumption shared by Hearsh, Griffin, and Lucas that each Center ought to receive tasks most closely related to its traditional strengths. Culbertson said that since each Center would need "considerable subsystem support" from other Centers, it would not be necessary to adjust the earlier advanced development assignments.<sup>140</sup>

Marshall's Work Package 1 also included the "common" module, propulsion, and the orbital maneuvering vehicle. Marshall's responsibility for the module involved not only the module structure, but responsibility for provisions for its data management, power, environmental and thermal control, and communications. JSC's Work Package 2 included the structural framework, Shuttle interfaces, attitude control, communications, and data management. Lewis received the electrical power system, and Goddard the platforms and responsibility to define provisions for instruments and payloads.<sup>141</sup> The Marshall-Johnson split was relatively even; estimates for program costs for each Center were close, and MSFC expected about 40 percent of the total Station work.<sup>142</sup>

### **Configuration and International Partners**

During the protracted negotiations leading to work package assignments, the Space Station configuration evolved at skunk works in Houston. People from other Centers joined JSC personnel under the direction of Hutchinson to elaborate the work begun by Powell's concept development group. The concept of a "power tower," a long boom with modules clustered at one end, best met user requirements, allowed for viewing and construction, and gave NASA the maximum capacity for Space Station growth. The Agency now had a reference configuration on which to base Phase B contracts.<sup>143</sup>

A reference configuration was not the only product of the skunk works. Level B management also developed during the four months the intercenter group met in Houston. Senior staff meetings evolved into the Space Station Control

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Board (SSCB), the Level B clearinghouse for integration decisions. Hutchinson used the skunk works to organize a staff that would carry the program into Phase B. He staffed most of the key positions with JSC personnel, and as people began to depart from Houston to return to their Centers, Level B took on an even more pronounced Houston cast. JSC was of course the Lead Center, but the domination of its people at interCenter meetings had exacerbated Center rivalry as Phase B got underway.

Marshall and the other Level C Centers also organized their space station teams. Lucas commissioned a Space Station Projects Office, and moved it out of the Program Development Directorate. Project Manager Powell would now report directly to Lucas. Cecil Gregg became Powell's deputy.<sup>144</sup> In April the four work package Centers awarded contracts to industry teams to conduct 21-month definition and preliminary design studies. Marshall's contracts, with Boeing Aerospace Company and Martin Marietta Aerospace, were valued at \$24 million, 36 percent of the total value of the contracts awarded. By the end of the summer, both contractors had established offices in Huntsville, and Boeing had announced plans to build an \$8 million building near the city's airport to support its Space Station work and other contracts with Marshall.<sup>145</sup>

While NASA was establishing its reference configuration, organization, and procurement approach, the Agency was also seeking to fulfill another aspect of its Space Station mandate: the involvement of international partners. The Agency courted ESA for months, and in February 1985 the Europeans agreed to advance a \$2 billion Italian-German project called Columbus as a means of ESA participation. In March, President Reagan and Canadian Prime Minister Brian Mulroney met in Quebec for what the press called the Shamrock Summit, and Mulroney announced that his nation would accept the American invitation to participate in the Space Station program. The next month Japan agreed to take part in the preliminary design phase, pledging a two-year commitment, and indications were that the Asian nation would likely continue beyond that date and design a laboratory for the Station.<sup>146</sup>

With the international partners on board, NASA worked to develop a baseline configuration. Finally the Agency adopted a baseline design first proposed by Marshall in the summer of 1985. The new configuration, a derivative of the power tower, used parallel twin booms in an arrangement NASA called the dual keel. Compared to the power tower, it had more mounting surface, greater

potential for growth, and an improved pattern for microgravity experiments. Marshall and Houston “went through with a lot of analysis and determined with the modules down at the lower end of the boom, where they were located on the Power Tower, we didn’t get exactly the right microgravity level,” according to Gregg. With the dual keel “we moved the modules up to the center of gravity of the Station.”<sup>147</sup>

### **The Perils of Complexity**

The fledgling program was experiencing problems by the summer of 1985, some of which were normal growing pains, some more serious. The most troubling difficulties were hinged either to the complex work package arrangement or to budget constraints. The Space Station program was so complicated that management guru Peter Drucker said its organization chart looked more like a maze than a matrix.<sup>148</sup> “We created an almost impossible management and engineering job,” explained James Odom, who witnessed Station development both from Marshall and from Headquarters. “I came from the school that the fewer interfaces you can have in a hardware program, between Centers, between contractors, the more straightforward, the easier it can be. Space Station doesn’t limit itself to doing it that simplistically. There’s hardly any way you can divide that thing up and not have numerous interfaces, but you don’t need thousands. I think that’s something that we did early on in the program that significantly complicated the design, the contracting, and the management.”<sup>149</sup>

The complicated ECLSS split, with JSC managing advanced development and MSFC managing the work package that included ECLSS, was one example. Marshall complained that the two tasks were not synchronized and that JSC was not responsive to Marshall direction. Culbertson, whose split had created the problem, insisted that MSFC had system responsibility, but directed Houston to continue its advanced development project. A similar problem existed on the attitude control system, with Center roles reversed.<sup>150</sup> “Centers compete rather than coordinate for work,” one Agency assessment concluded. Interfaces between work packages were difficult, and sometimes nonexistent; some contractors claimed that their Centers had directed them not to deal with contractors from other work packages. Neither Level B management nor the SE&I system appeared capable of holding the program together, and NASA began to worry that it was buying four “indigestible” products—work packages that would not mesh.<sup>151</sup>

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Money had been a constraint in every NASA program since Apollo, but with Space Station the problem became particularly acute. By 1985 it was already clear that the Reagan commitment to build a space station within a decade was unlike the Kennedy vow to reach the Moon in a decade, and money was a fundamental difference. The Beggs pledge that NASA could build an \$8 billion space station left NASA hedged in. Nineteen eighty-four was the only year in which NASA received its full space station budget request, in part because the Agency had limited itself to a modest \$150 million, barely enough to cover start-up expenses. The decision forced NASA to design to cost, and now a year later costs had already begun to rise. Some in NASA claimed the Agency was costing the design rather than designing to cost. Problems external to the Agency exacerbated NASA's budget squeeze; federal deficits prompted Congress to trim all discretionary programs, and NASA suffered with other independent agencies.<sup>152</sup>

The budget crunch forced Culbertson to reexamine the Space Station program with an eye to "reducing or deferring development costs." On 14 August he directed Hutchinson to initiate a review involving both Level B and Level C, and to examine both cost reductions and changes that might affect system capability. The review, or "scrub," soon became known as "scrub mother," the first of several such exercises compelled by budget ceilings.<sup>153</sup>

Program reviews increased the already palpable tension between the Centers, especially since it focused attention on perceived shortcomings at Level B. Powell complained to Lucas that JSC was not delegating responsibility, and was micromanaging even tasks in the \$50,000 range. He claimed that JSC failed to communicate; rather Level B was "in charge," and acted as if "We will tell you what we want you to know, what to do, and when."<sup>154</sup> Gregg remembered being "completely overpowered" in meetings at JSC. "You'd get down there in the conference room that would hold a hundred people, and it would be completely full of people coming in from all the [JSC] engineering and development divisions and offices. . . . It was a pretty difficult environment to work in." Disputes "pervaded the whole activity."<sup>155</sup> Powell remembered a meeting of the Configuration Control Board at which Marshall, Lewis, Goddard, and Headquarters each had 1 representative, and JSC had 16—and each individual had one vote.<sup>156</sup>

Matters came to a head at a space station management council meeting at Marshall on 24 October 1985. Hearth presented the findings of his

investigation of systems integration problems. He pointed first to problems at the top: people perceived Level A to be weak, and “not in charge,” and everyone was uncertain as to exactly what the Level A role was to be. Problems at Levels B and C were manifest. Key people at Level B were inexperienced, and the program manager was tired, frustrated, and “up-tight.” It was unclear whether JSC was lending sufficient institutional support, and whether Level C accepted Level B authority. The Centers were plagued by excessive interfaces, Hearth said. Work packages had been driven too much by trying to preserve equality between JSC and Marshall. The Centers were too protective of turf, and were wary of international participation since foreign partners might absorb parts of their work packages.

What could be done? Some problems could be addressed relatively easily; JSC could assign more experienced people, and responsibilities at each managerial level could be defined. But the problem ran too deep for cosmetic solutions. The work packages would have to be redefined in order to simplify interfaces, allow for efficient integration, and facilitate international participation. Realignment should concentrate on Center technical capabilities, not on the relative size of the work packages or the dictate to provide “something for all Centers.”<sup>157</sup> Hearth’s report carried weight in Headquarters, where Culbertson was perturbed with continued intercenter rivalry.<sup>158</sup> A consensus emerged within the Agency that a change in work packages was necessary, although no one could yet define it.

The next several months encompassed the most chaotic period in NASA’s history. Beggs took an indefinite leave of absence from the Agency in December as a result of fraud charges dating to his tenure at General Dynamics. Although the charges later proved groundless, Beggs’s departure brought William Graham to the NASA helm as acting administrator. Graham, however, had been in the Agency for only eight days, so Culbertson became NASA general manager in charge of day-to-day activities.<sup>159</sup> Then JSC Center Director Griffin and Space Station Program Manager Hutchinson resigned, to be succeeded by Jesse Moore and John Aaron. Budget pressure also continued, and on 23–24 January 1986, Space Station planners discussed ways in which the “scrub mother” exercise might reconfigure Station to the \$6.5 to \$7.5 billion range.<sup>160</sup> The *Challenger* tragedy on 28 January thus caught NASA and the Space Station program in transition.

The *Challenger* accident was devastating to all of NASA, and the Space Station program was no exception. Station depended on Shuttle, and the grounding of the Shuttle fleet guaranteed further delays to a program already plagued by budget and management problems. Most immediately, the accident meant delays in thermal and materials experiments deemed to be “of critical importance to Space Station design.”<sup>161</sup> Culbertson directed that the Space Station Office consider “lifeboat” rescue capability for the Space Station.<sup>162</sup>

### **Reorganization**

The six months following the *Challenger* accident witnessed a wholesale reexamination of the Space Station program that resulted in a realignment of work packages, abandonment of the Lead Center concept, and establishment of a new Headquarters program office to manage Station. Marshall, buffeted by the repercussions of *Challenger* and preoccupied by the investigations that followed the accident, offered comments on the proposals floated by Headquarters and JSC, but for the most part Headquarters directed the reorganization. New leadership took charge in Houston, Washington, and Huntsville, and sought answers to an old problem: how to find the delicate balance between Center strengths and Headquarters’ managerial responsibility.

The path to these tumultuous changes followed two tracks. With Culbertson stepping up to serve as NASA’s general manager, Hodge took over as acting associate administrator in the Space Station Office and initiated a review from within the Space Station Program Office. He directed Marc Benisimon to lead a team dominated by Headquarters but comprised of representatives from all three levels to recommend a new work package split.<sup>163</sup> The other review brought back an old NASA veteran, General Sam Phillips, who had managed the Apollo program. Acting Administrator Graham asked Phillips to conduct a review of NASA management, and particularly of Space Station. Both studies had dramatic impact on the structure of the program.

Hodge’s evaluation produced two alternatives. JSC and its contractor, Rockwell, advanced a plan that would have designated a single prime contractor and shifted much of Marshall’s work to Houston. This “primary integration” approach, JSC argued, would provide “cost effectiveness, clear accountability, and superior flexibility.”<sup>164</sup> The other Centers, including Marshall, preferred to stick more closely to the original structure.<sup>165</sup> Lucas argued that although Marshall had

opposed the original split, “the present work package definition is workable,” and that to make anything other than minor changes would be disruptive to the program as it neared Phase C/D.<sup>166</sup>

Hodge’s recommendation, which he called “equal accountability,” retained the four work packages of the original agreement. It made a significant modification in task definition, however, and Marshall Project Manager Powell influenced the change. NASA should “separate the inside from the outside,” Powell suggested. “There’s a very natural separation there,” he remembered telling Headquarters. “Anything outside ought to be those people who are responsible for basic structure, and inside ought to be those people responsible for the basic module.”<sup>167</sup>

Hodge’s “inside/outside” split awarded Marshall the “inside.” MSFC would develop all systems related to the “pressurized environment,” which included the modules and related hardware such as tunnels, nodes, and interconnects. Houston had the “outside,” or the “structure/architecture.” JSC thus retained the truss and had responsibility for subsystems including attitude control, data management, and communications and tracking. The “inside/outside” split divided subsystems like thermal and communications, which had previously been assigned to one Center. The most significant implication was that each Center now had responsibility for one of the other’s traditional specialties: JSC had propulsion, Marshall had ECLSS.<sup>168</sup>

When Graham suggested bringing in General Phillips from retirement to study space station management, Hodge told Graham, “If you give it to Sam, you can almost guess what your answer is going to be, and it is not what we’ve got.” Hodge expected that Phillips, the former Apollo manager, would lean toward the Apollo management concept, which ran the program out of Headquarters rather than rely on a Lead Center. Phillips agreed to head the review, and accepted the task of examining station management, work package distribution, and systems integration.<sup>169</sup>

Phillips assembled a team that included former NASA Associate Administrators Mueller and Mathews. After discussing Station management with members of the Space Station Program Office in Washington, he visited each of the field Centers and their contractors. On 16 June, the team visited Marshall for two days of meetings with representatives of the Center and its contractors,

Martin Marietta and Boeing.<sup>170</sup> “Practically the whole of Marshall’s Space Station role hinged on that visit,” according to Powell.<sup>171</sup>

When Phillips returned to Washington to present his findings, James C. Fletcher had taken office as NASA administrator. Fletcher, who had headed NASA in the early 1970s, returned at the request of President Reagan to oversee the Agency’s recovery from the *Challenger* accident. Fletcher was preoccupied with Shuttle, but had opinions about Station problems that predisposed him to accept recommendations for changes in management. Reviewing the flip charts of a Station review from several months earlier, Fletcher wrote on the cover: “JSC/MSFC split still an abortion,” and “Bottom line: Lead Center concept would work but it depends on personalities. Level B did not have quality it deserves.”<sup>172</sup> Phillips briefed Fletcher on 26 June. His most dramatic recommendation was that the Lead Center concept be abandoned, to be replaced by a strong program management office located near Headquarters but outside of Washington, removed from Beltway politics. The new office would have direct line authority to the field Centers. A branch office in Houston would coordinate system integration. He accepted the “inside/outside” split advocated by Hodge, modified to shift habitation module and airlock outfitting to Marshall. Within a week Fletcher announced acceptance of Phillips’s recommendations and named Lewis Director Stofan associate administrator for Space Station.<sup>173</sup>

Marshall was the greatest beneficiary of the announced changes. The Center stood to increase its share of Space Station work from 31 to 44 percent, while JSC’s would have decreased from 43 to 29 percent.<sup>174</sup> For Houston, the timing of the announcement could not have been worse; plunging oil prices depressed the Houston economy, and JSC Center Director Moore had just announced that he was retiring and thus would not be able to guide the transition. Houston newspapers screamed that JSC might lose 2,000 jobs, and the Texas congressional delegation enlisted Vice President George Bush to fight the decision.<sup>175</sup>

Fletcher retreated, announcing a 90-day cooling-off period to reexamine the changes.<sup>176</sup> Politics forced NASA to abandon another of its work package guidelines: that division of tasks should not be driven by traditional balance of funding between JSC and Marshall. Adjustments, including retention of the airlock at Houston, enabled NASA to give Houston and Marshall each about 36 percent of Space Station work.<sup>177</sup>

### **Cutting Costs**

The *Challenger* accident guaranteed that Congress would scrutinize space station planning because it called into question NASA's technical expertise in a way that even the Apollo fire had not done. That it struck during a time of increasing concern over mounting federal deficits increased NASA's dilemma, for the Agency would now have to face criticism not only of the program's structure, but of its costs. During Apollo, NASA never had to prove that its program was cost effective. Such criticism became a factor during Shuttle development, but never overwhelmed the program. After *Challenger*, the public treated NASA as just another federal Agency competing for scarce resources. With the federal budget deficit climbing at an astonishing rate, agencies like NASA whose budgets were subject to annual review were vulnerable. Space station, a high-profile program with increasing costs and ill-defined purpose, was an easy target for cuts. Space station would have to prove itself during each budget cycle, and on difficult terms. In this environment, space station had to overcome two formidable obstacles: it was a visionary program, with returns measured in terms more related to the human spirit than cost effectiveness; and its promised material returns were far in the future and difficult to quantify.

NASA reorganized space station as part of the post-*Challenger* overhaul. Within two months in the spring and early summer of 1986, Fletcher and Stofan came aboard at Headquarters, and the Center Directors of both JSC and Marshall left the Agency. Lucas retired early in July after a 30-year career at ABMA and Marshall. On 29 September, J. R. Thompson, a 20-year NASA veteran who had managed the Shuttle main engine project at Marshall, took over as the new Center director. Fortunately project personnel remained stable at all four work package Centers; Powell continued to run Marshall's Space Station Projects Office. Managerial stability, however, was less crucial than costs. NASA had to defend the Station from cost reductions. Cuts forced delays, which increased criticism the next budget round.

In the fall of 1986, NASA conducted a review of space station design. A Configuration Critical Evaluation Task Force (CETF), under W. Ray Hook at Langley, evaluated Station design, concentrating on problems related to launching, assembly, and maintenance. "The CETF allowed us an opportunity to just stop for about a month and see where we were," explained O'Keefe Sullivan, one of Marshall's representatives. "We had had four work packages

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working pretty much independently during Phase B, and there had been no real coordination and compiling of what each of the elements [was doing]. All four work packages worked together with our best weights [and] power requirements, and put together a coordinated assembly sequence.”<sup>178</sup>

Charles Cothran, another Marshall representative, worked on a reevaluation of how many shuttle flights it would take to launch and assemble the Station. Cothran’s work demonstrated that early planning projecting 10 shuttle flights was overly optimistic, and gives one indication of why Congress attacked the \$8 billion budget figure. “We went from 10 launches to 16 launches,” Cothran explained, “and it was very obvious that we couldn’t do it even in 16 launches, because we had negative margins on almost every load that we sent up. . . . And we had some hardware manifested at zero weight, which you know is unrealistic. We knew there was at least another flight or two of equipment that had to go up.”<sup>179</sup>

The CETF review, which culminated in December, also recommended design changes that affected Marshall’s participation. The team suggested enlarging Marshall’s nodes and tunnels; larger “resource” nodes could be used to house equipment, thus helping reduce EVA time. Finally, the review advocated still another modification of work packages, giving Marshall responsibility for engine elements of the Station propulsion system.<sup>180</sup>

Upward revision in the number of shuttle flights required to build Space Station was but one of many factors increasing the estimated cost to completion. NASA had decided that an \$8 billion Station was impossible, and in 1987 the Agency began to revise its estimates. The Agency informed the administration that it would cost \$14.5 billion in 1984 dollars (\$21 billion in 1987 dollars). An internal analysis suggested that NASA would need a \$3.5 billion annual budget, while the administration had planned Station spending to peak at just over \$2 billion per year.<sup>181</sup> Although Hodge acknowledged political, complexity, and administrative problems, he placed part of the problem at the Centers. NASA did not really “design-to-cost,” Hodge believed, but rather practiced “cost avoidance” or “cost cutting.” Center engineers were content to let costs rise, since this benefited their organizations. Inadequate contractor oversight caused duplication and “uncontrolled manpower loading.”<sup>182</sup>

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Myers, formerly head of manned space flight, returned to NASA late in 1986 as deputy administrator and immediately began to look for ways to cut Station costs. In doing so, he examined the roles of the Centers; his plans, had they been adopted, would have had a dramatic impact on Marshall. One possibility was to lower sights and develop an “austere” station by eliminating vertical beams and using only one cross beam, reducing the data system, and developing only one American lab/hab to be manned by a crew of five. He proposed dropping Lewis and Goddard from the work packages, suggesting that “by getting the Manned Program back in the three manned Centers, we even improve our management ability.” These shifts “would reduce MSFC’s workload slightly so they could take on the heavy lift launch vehicle.”<sup>183</sup>

Myers also considered eliminating all space station work at Marshall. He believed it would be necessary to “reschedule” space station, to “half-size” the lab and hab modules, and plan for a man-tended rather than a permanently manned system. Then, since the modules would be smaller, “and since MSFC is so busy with ELV [expendable launch vehicles] and new engines, put MSFC work at JSC,” he wrote. “MSFC would be out completely. Their contractor would be managed by JSC.”<sup>184</sup>

Myers’s ruminations never became Agency policy, but they reveal the character of the program early in 1987. For the second-ranking official in the Agency to consider such drastic action on the heels of a contentious work package revision demonstrates the program’s instability, high-level doubts about its Station plans, and organizational problems.

Such fears were justified. The Congressional Budget Office suggested that in light of the \$14.5 billion estimate, the Agency should cancel Space Station. Fletcher worried that the administration’s commitment had wavered, that the international partners were getting cold feet, and that the Agency had lost control of Station and was losing its competitive edge in manned space flight. NASA delayed beginning Phase C/D for at least two years. Delays forced a schedule slip of at least two years. In March the White House agreed to a two-phase space station “stretchout” program that would result in a scaled-back station comprised of main truss, four modules (two American and one each for Japan and ESA), and a solar array power system.<sup>185</sup> The second phase would add two “keel” beams, provisions for more power, and a platform.<sup>186</sup>

Space Station was safe for the time being, but the program was now under unrelenting scrutiny. Powell insisted that the changes would not affect Marshall's work package, that there would be no reduction in the Center's hardware responsibilities. It "simply means that we will pay for the station as we go," he asserted.<sup>187</sup>

### **Moving into Phase C/D**

With space station breathing new life, NASA prepared to initiate Phase C/D development. Implementation of the programmatic changes recommended by the Phillips Committee and the shift of management to the Washington area preceded publication of the call for contractor bids. Headquarters sought to control the Centers, but its new program office also introduced new managerial problems.

In the spring of 1987, Headquarters opened a new program office in Reston, Virginia. The new Level A–Prime replaced Houston's Level B.<sup>188</sup> Unfortunately the Reston office also introduced another level of bureaucracy, and instead of simplifying the program's interfaces, added complexity. The Centers complained about Reston micromanaging. The new office was "too involved in the next level down," according to Lee, who was Marshall's deputy director at the time of the change. "They never seemed to understand exactly what their role was." JSC's Denny Holt, who worked on systems integration, described what he called "the initial Reston fix": "Instead of taking the Level B documentation which was about the right level because it had been argued by all of us, they took it and processed 7,000 changes [and] added detail that you couldn't believe." Lee insisted that Reston never "got control of defining the program at the systems level."<sup>189</sup>

The frustrations prompted NASA, the White House, and the Defense Department to commission a study by the National Research Council (NRC). Seamans, a former NASA associate administrator now on the faculty of the Massachusetts Institute of Technology, headed a 13-member panel whose report contained good and bad news. The first part of the report, submitted in July, raised the frightening prospect of a \$32.8 billion space station (in 1988 dollars, compared to the NASA estimate at the time of \$19 billion).<sup>190</sup> The NRC full report in December concluded that Space Station would be a challenge "of formidable proportions," one that would stretch for two or three decades and thus

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could not be approached as a “one administration” program that could be built “on the cheap.” The committee, however, endorsed NASA’s configuration and its conception that the Block I station was only a starting point. The NRC had little to say about individual Centers, but supported developing advanced solid rocket motors for the Shuttle, which would be assigned to MSFC.<sup>191</sup>

Even as the NRC review proceeded, NASA finally released the RFPs for the work packages late in April 1987. Marshall’s solicitation, valued at \$4.5 billion, spelled out two options: one for a phased program, the other for an enhanced configuration program.<sup>192</sup> “We were going out with four RFPs at the same time, and we were trying to get as much common language and common items as we could, so we didn’t have four completely disjointed contracts,” explained Gregg, who chaired Marshall’s Source Evaluation Board.<sup>193</sup> Marshall’s Work Package, as it now stood, included two pressurized modules (one “lab” for microgravity research and one “hab” for eight crew members), three logistics support systems, four resource node structures, the ECLSS, an internal thermal management system, and internal audio and video systems.<sup>194</sup> In July, Boeing and Martin Marietta submitted proposals for Marshall’s Work Package One.

The importance of the submissions to the contractor and the Agency, the requirement for security, and the depth of detail and sheer size of the proposals made the Source Evaluation Board’s task a difficult one. Martin Marietta’s two-million page proposal weighed 8,780 pounds, and filled 186 boxes. Boeing’s 6,000-pound proposal filled 121 boxes.<sup>195</sup> Gregg set up shop in an office building on Huntsville’s Memorial Parkway and posted 24-hour security. More than 200 people assisted the Board in its evaluation, some examining only small details, while others spent weeks with the group.<sup>196</sup>

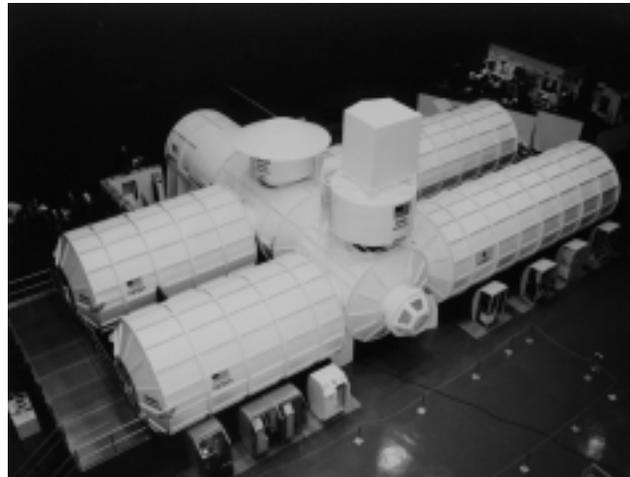
On 1 December, Fletcher announced the successful bidders for each work package. Boeing won the competition as the prime contractor for the Marshall work package on the basis of its approach to key areas like systems engineering and integration, design and development, and program management. Boeing would have support from Grumman, Lockheed, Teledyne Brown, and TRW. NASA expected that the award might bring \$800 million and 2,000 jobs to Huntsville.<sup>197</sup>

## Development Work

While management worried about administering the Space Station program, Marshall's engineers and contractors began work on design and development. NASA had decided early that the Space Station would rely as much as possible on pre-existing technology, and most Station officials acknowledged that the programmatic challenges were greater than the technical challenges. Nonetheless NASA relied on state-of-the-art technology in some areas.

The ECLSS provided Marshall the most demanding challenge. ECLSS had seven subsystems: temperature and humidity control, atmospheric control and supply, air revitalization, the water reclamation and management system, waste management, fire protection and suppression, and EVA support.<sup>198</sup> It was a technological driver because other subsystems depended on ECLSS development. ECLSS relied on old technology, but Marshall sought improvements based on lessons from *Skylab* and Spacelab. "We went back and reviewed all those anomalies and made sure that . . . our design would side-step any similar type problems," according to Humphries.

In the early 1970s NASA used Marshall's powerful Saturn rockets to deliver thousands of pounds of water for *Skylab*. The Saturns were no longer available, and the shuttle's smaller lifting capacity would be used for other cargo. "The biggest difference between *Skylab* and Space Station is the fact that we didn't [have] oxygen and water loop closure," Humphries explained. For the first time, NASA would be "closing oxygen and water loops," which meant that Marshall had to design systems for recovering waste water for reuse and extracting oxygen



Space Station Freedom *mock-up* at MSFC in December 1991.

from CO<sub>2</sub> for rebreathing.<sup>199</sup> “It’s imperative to have any practical space station, that you have to recycle the water,” explained Hopson. To do so was essential: “If we have the right kind of system, there’s no reason why you’d ever have to take water up,” Hopson said.<sup>200</sup>

“The main source is urine, and another is condensate,” Hopson continued. “The toughest is urine and there you normally use some sort of distillation process. And power is at a premium on a space station, so you’ve got to have some process of using heat for distilling and then later you condense the vapor. But you have to be very careful not to come up with a system that uses so much power that it’s impractical.”<sup>201</sup>

Another of Marshall’s responsibilities, the habitation module, demanded fewer technological developments. “There has to be some innovative thinking of exactly how to put everything together,” explained Axel Roth, who headed the project beginning in 1987. “But I don’t see any pushing the state of the art.” The principal problem in designing the habitation module was that “we’ve got a limited amount of space to do a lot of things in,” Roth explained. To compensate for the crowded conditions, designers decided to separate the module into three areas: a quiet area for the crew’s quarters on one side, a wardroom/galley on the other side where more activity would take place, and an intermediate area for lower-use activities, such as a health maintenance facility with its exercise machines.<sup>202</sup>

While the “Hab” would provide living space, the “Lab” would be the workplace of Space Station. Marshall’s responsibility for the laboratory module evolved as the program changed. Originally, NASA planned to have two labs, one for life sciences to be developed by Goddard, and one for materials under Marshall. The two Centers had different ideas regarding how the labs should be structured; Goddard wanted the lab divided into floors. “We referred to [the Goddard design] as a bologna slice,” recalled Marshall’s Walt Wood. “We had the orientation down the longitudinal axis of the lab.” The two Centers conducted studies, and Goddard agreed to use the Marshall orientation.

Budget reductions forced NASA to cut back to one lab incorporating both life science and materials research, and realignment gave responsibility to Marshall. Designers relied on racks to provide access for experimenters. “We spent a lot of time and a lot of effort trying to determine the dimensions of a rack—its

depth, its size, trying to get the most volumetric efficiency we could in a rack,” Wood explained. Eventually they settled on four “stand-offs,” each supplied with power, fluid lines and ducts, housing a total of 44 racks.<sup>203</sup>

While some problems were unique to each module, each had common concerns. Contaminants posed a serious challenge in a closed-loop system. As Hopson explained, “Once you close the door you have no ventilation anymore. Some of these things you never worried about before become problems.” Controlling microbes is vital, since “you’re handling some pretty dirty stuff” in an environment favorable to growth. Both water and the gasses in the module atmosphere would have to be tested constantly, and the Center and its contractors had to design holding tanks and monitoring apparatus, as well as biocides and the catalytic oxidizer to eradicate contaminants.<sup>204</sup>

### **Systems Integration**

Systems integration was a particularly difficult problem that had troubled Space Station plans from the beginning. Robert Crumbly of Marshall’s Systems Engineering Office described the process as “making apples and oranges add up together.”<sup>205</sup> Initially systems engineering involved defining requirements, contract specifications, and interfaces, and developing program documentation. As the program moved into Phase C/D, the job evolved into one of setting requirements to verify hardware and monitor contract performance.

Making sure that all the systems work together was anything but simple on Space Station. “The integration role and the coordination role with Level II and other Centers is probably greater than any other program we’ve ever had here at Marshall,” according to Crumbly.<sup>206</sup> In order to coordinate between systems, subsystems, and work packages, NASA relied on two different types of control documents that would alert people to changes affecting their areas of responsibility. Architecture Control Documents (ACD) set forth the Station’s structure, and Interface Control Documents (ICD) like those used in the Shuttle program addressed overlaps between systems. If JSC introduced a change in truss structure, for example, it might affect Marshall’s modules; ACDs would alert Marshall of the alteration. An interface working group with representatives of each of the Centers resolved differences.

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Integration meant close work with other Centers, particularly with JSC, and although the two Centers squabbled over division of responsibilities, people at the two Centers had worked together for years and knew how to cooperate. “There has not been acrimony,” insisted JSC’s Holt. “Quite frankly, at the working level, we’ve never had a problem of getting to an answer with Marshall.” Both Centers have typically “let the technical solutions bubble and then go in at the last minute and make decisions. I think that’s been almost the modus operand of Marshall-JSC operations over the whole time I’ve been involved.”<sup>207</sup>

Interfaces with contractors were another matter. Because of the division into work packages, contractors under different work packages had difficulty communicating with one another, even though their responsibilities often overlapped. If Boeing had a problem that related to an interface with JSC’s contractor McDonnell Douglas, Boeing could not approach McDonnell Douglas directly. Instead, they had to report to Marshall’s project office, which in turn would approach JSC’s project office, which would then contact McDonnell Douglas. It was a cumbersome bureaucratic system. Marshall Center Director Lee explained that “Any time you have a complex system like this and you’ve got to put . . . one or two government people in between two contractors to do even the simplest kind of thing, then you’re inefficient.”<sup>208</sup>

In April 1988 Odom, who had managed the Shuttle external tank and the Hubble Space Telescope for Marshall, replaced Stofan as associate administrator for Space Station. One of Odom’s goals was to find a solution to the impasse in contractor-to-contractor communications. He proposed an “associate contractor” relationship. “What I wanted to do,” he explained, “was put into the contracts the responsibility that if Boeing and if McDonnell Douglas had a problem, their first responsibility was to go very quickly, find the most economical way to fix it, regardless of what it would cost, which one would cost more money. Put the responsibility on them to come back to the government with one or two solutions and let the government pick the best solution.”<sup>209</sup> Grumman, as integration contractor, would coordinate between work package contractors, but Odom believed the Grumman contract was too limited to allow them to improve communication significantly. Lee said “it’s difficult to bring an outside contractor in to be systems engineer on somebody else’s hardware.”<sup>210</sup> JSC’s Holt believed that Odom’s plan would have succeeded in giving prime contractors incentive to work out problems, thereby bringing fewer problems to the Government. Unfortunately, however, neither the contractors nor many

in NASA were accustomed to operating in such a fashion, and “as soon as Odom and [his deputy Ray] Tanner left, that went away overnight. Reston took that apart in five seconds.”<sup>211</sup>

### **Hanging On**

During Odom’s year as associate administrator, Space Station budget battles became institutionalized. Odom and Fletcher recognized how much the struggle to justify Station had impacted the program the previous year, and tried to prevent a recurrence. “Dr. Fletcher and I very deliberately decided it was time to really decide if the nation and/or the Congress really wanted a Space Station Program,” Odom remembered. Congress proposed level funding, and Odom worried that “we would have just kept going treading water and not making any real progress.” Odom and Fletcher convinced Congress to fund Station at \$900 million for Fiscal Year 1988.<sup>212</sup> They had won only a skirmish; Space Station would remain controversial well into the 1990s. When Fletcher left the Agency, he chose to emphasize funding problems in his valedictory address: “Restudy after restudy simply reinforces the conclusion that *Station Freedom* is well-conceived and well-managed, but very sparingly financed. There is simply no room for further trimming or shaping or cutting.”<sup>213</sup>

The Space Station program became one of the most debated federal programs in the 1990s. Congress treated NASA like a spoiled child who had been given too much, and now needed to be brought up short. Congress restricted the Agency’s spending, demanded rescoping, and then chastised the Agency for failing to make more progress. Costs increased, in part because of the stretchout. “You have funding instability when you have increase in cost,” Lee explained. “That increase in cost gets reported, and then you get criticized for it.”<sup>214</sup> The budget system was not designed for programs that stretched for decades. Apollo astronaut Wally Schirra highlighted the difference between the lunar program and station when he told a Huntsville audience in 1989, “We need to look at the space station as at least a 25- to 30-year program, not a quickie like going to the moon and back.”<sup>215</sup>

Delays and stretchouts contributed to a decline in support for station. The public mood shifted, and Congress challenged Station at every turn. Even within the space community, people wearied of the lack of progress. As early as 1988, Marshall’s Associate Director for Science Charles R. Chappell, worried about wavering commitment among scientists:

“This process that we have gone through with Spacelab mission cancellations has served to scare away many of the scientists who would be oriented toward doing science on the Space Station. They just hung with it, some of them for a decade, before they gave up. They wrote a proposal. It was a great idea. It got selected, and then they got money dribbled to them over the period of a decade, never coming to fruition. They just, at some point, say I can’t stay with this any longer.”<sup>216</sup>

Many factors coalesced to place Space Station in constant peril, some beyond NASA’s control and others of the Agency’s own making. Space Station, as Odom has said, “came about at a time when the nation didn’t know what it wanted to do either nationally or internationally.”<sup>217</sup> NASA’s programs had always been political, but politics came to dominate Space Station in an unprecedented way. The driving force behind the division of space station work was an effort to ensure a geographic spread that would maintain the support of the aerospace community and Congress.

NASA, for its part, was unable to articulate its vision in a way that appealed to the public imagination. When NASA in the mid-1970s turned to industrialization in space as a justification, it started down a path that allowed the Space Station to be evaluated on the basis of what it could produce, rather than on the basis of scientific research or a visionary quest for humankind. It was a rationale without hope of short-term fulfillment, and placed Station in the wash of Shuttle’s unfulfilled promise. NASA had made similar pledges for Shuttle, arguing on the basis of cost-per-pound to orbit and number of missions per year, raising expectations to levels that the Agency never came close to fulfilling.

The highly political context in which the Space Station program matured often left Marshall on the periphery. Marshall people, to be sure, played key roles throughout; the story of Space Station could not be told without reference to Wernher von Braun’s and Koelle’s visionary designs, the pioneering contributions of the engineers who developed *Skylab* and Spacelab, Powell’s leadership of the Concept Development Group, or Odom’s leadership as associate administrator. But the Center was often acted upon rather than acting. Sometimes this was by intent, since Space Station was one program over which Headquarters asserted unusual control. Lee, for example, was one of the more experienced people in the Agency in dealing with international partners, yet when asked about how much he was involved in developing the international role for

Station, he replied, “Not as much as I would have liked to have been and thought I should have been.” Frequent changes in the program also had the effect of leaving Marshall to respond to the latest modification. Marshall, along with the other Centers, faced formidable external obstacles throughout Space Station development. The internal (within NASA) obstacles were primarily programmatic, since the technological challenges were less than they had been on previous projects.

Space Station has challenged Marshall in ways unlike previous programs. As an overtly political program, Space Station has drawn the Center into the political arena. “We can’t lobby, but we can give information,” Lee explained. “We’ve done more of that on Station than I ever remember we’ve done on any program here, and we’ve been asked to do that by Headquarters.”<sup>218</sup>

In spite of the problems that plagued the program, work on Space Station displayed Marshall strengths. The Center had unusual vision; more than 30 years after Marshall engineers produced the first Space Station study, their professional heirs were working to fulfill their dreams. A culmination of more than 30 years of work in manned space systems, space station demonstrated the legacy of Apollo, *Skylab*, Shuttle, and Spacelab. Marshall engineering talent helped to solve the problems posed by ECLSS, Station’s most challenging technology. And Marshall engineers and managers learned to operate a technological program under unprecedented political, budgetary, and bureaucratic pressure.

In 1993 President Bill Clinton ordered another redesign of Space Station in order to reduce costs, streamline management, and increase international involvement. The post-Cold War relationship with the former Soviet Union made possible closer ties with the Russians, who now joined the Americans, Canadians, Europeans, and Japanese as partners.

Teams at NASA Centers developed three new designs, and the administration selected the proposal designated “Alpha.” Although the new design preserved 75 percent of the hardware designs of the old program, it was a fundamentally new program. Now known as the *International Space Station (ISS)*, the new design slashed projected completion costs from \$25.1 billion to \$17.4 billion, and cut operating costs in half. The new Station would have six laboratory modules instead of the three planned for the old design. As in the old design,

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Canada would provide a remote manipulator arm and Japan and the Europeans would provide lab modules. The Russians would contribute hardware elements and employ their *Mir* Space Station in collaborative operations with the American Shuttle during the first phase of the *International Space Station* program.<sup>219</sup>

In August 1993 Headquarters designated JSC “host Center,” meaning that the program office would operate out of Houston, but that JSC would operate only as “host,” and not have the authority of a Lead Center. The change took into account earlier difficulties; there would be one prime contractor, which NASA hoped would minimize the troublesome systems integration problem. Award of the prime assignment to Boeing, Marshall’s contractor, reflected well on the excellent working relationship that the company and the Center had experienced. Lee expected only minimal impact on Marshall: “I think we are still reasonably sure that there’s going to be a pressurized module within our work package and that there’s an environment control system that’s going to be done here. We’re using quite a bit of our facilities. I see us [as] not doing any less than we were doing before. The problem is the money. We know that the overall cost of the station is going to come down. That means everybody’s dollars are going to come down and that means we have to again find ways to do it with less money. That would be the biggest challenge.”<sup>220</sup>

Reorganization gave Space Station another new beginning. The new program outlined a three-phase schedule. Phase I began in 1994, employing the Shuttle and the Russian Space Station *Mir* for preliminary work and experiments. Phase II, scheduled to run from 1997 to 1999, projected assembly of the core of the *ISS* from American and Russian components and the beginning of Station research. In Phase III projected completion of the *ISS* by 2002, and initiation of 10 years of international experiments.<sup>221</sup>

As the new program began, Marshall remained ready to “do all or any part,” as Lucas had said a decade earlier.<sup>222</sup> Key elements of the *ISS*, including the habitat module, underwent fabrication in MSFC’s Space Station manufacturing building.<sup>223</sup> The Center supported Station testing, and prepared to manage payload operations and utilization. Marshall engineers worked in-house to develop the first major experiment facility for the *ISS*, the Space Station furnace facility (SSFF) for microgravity materials science research.<sup>224</sup> From the origins of concepts in the early 1960s to the fabrication of elements in the 1990s, and from *Skylab* to *Freedom* to the *International Space Station*, Marshall continued to be at the center of space station development.

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- 5 Dr. John D. Hilchey/PS02, OHI by Thomas Gates/MSI, 6 November 1987, Huntsville, Alabama, p. 5.
- 6 John Massey/EH01, OHI by Thomas Gates/MSI, 6 October 1987, Huntsville, Alabama, pp. 1, 4.
- 7 Williams OHI, pp. 5–6.
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- 12 Hilchey OHI, p. 16; Massey OHI, p. 9.
- 13 See, for example, Hilchey OHI, pp. 10–12.
- 14 Von Braun, handwritten note on Carter to von Braun, 13 November 1962, Space Station (von Braun) 1962–1968 folder, Drawer 52, MSFC Center Directors' Files.
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- 16 Shea to Distribution, 17 October 1962; John E. Naugle to D.M. Shoemaker, Deputy Director for Systems, Office of Manned Space Flight, 14 November 1962; Orr E. Reynolds to Shoemaker, 10 December 1962; Deputy Director, Office of Space Sciences to Shoemaker, 21 December 1962, Correspondence File, box 1, Space Station Series, JSC History Office; Gruen, pp. 16–17.

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- 18 "Summary Report, Future Programs Task Group," January 1965, p. 4, Space Station Series, NASA Documents, box 2, JSC History Office.
- 19 See Chapter 4.
- 20 Von Braun to Major General David M. Jones, Acting Director, Saturn/Apollo Applications, 16 December 1965, Correspondence File, box 4, Space Station Series, JSC History Office.
- 21 "Presentation for Dr. Paine on the Space Station," 5 December 1968, p. 9, Correspondence File, box 7, Space Station Series, JSC History Office.
- 22 Space Station Requirements Steering Committee, "The Needs and Requirements for a Manned Space Station," Volume 1: Summary Report, 15 November 1966, p. 82, Space Station Series, NASA Documents, box 2, JSC History Office.
- 23 Logsdon and Butler, p. 223.
- 24 NASA OMSF Advanced Manned Missions Program, "Space Station: Phase A Report," 21 November 1968, Correspondence File, box 7, Space Station Series, JSC History Office.
- 25 Von Braun to Paine, 24 January 1969, Space Station No. 2 folder, MSFC Center Directors' File; Logsdon and Butler, p. 224.
- 26 MSFC MSI Station Historical Documents Collection (STHDC) No. 0123, Entry 0646, 5 December 1968.
- 27 William A. Brooksbank, OHI by Thomas Gates/MSI, 2 May 1990, Huntsville, Alabama, p. 4.
- 28 Hans H. Maus to MSFC Distribution, 16 December 1968, 19/6 MSF Institutional Planning Study, Memo to Jay Foster from Dr. Lucas 1/20/69 folder, Terry Sharpe Files, Drawer 111, MSFC History Archive.
- 29 Maus Weekly Notes, 16 December 1968, 19/6 MSF Institutional Planning Study, Memo to Jay Foster from Dr. Lucas 1/20/69 folder, Terry Sharpe Files, Drawer 111, MSFC History Archive. MSFC was willing to "assume [that] other Centers will be responsible for the new logistics spacecraft and the biological, medical, earth resources and meteorological experiments."
- 30 Manpower for experiments and experiment integration would have peaked the following year with 1,300 civil service and 5,000 contractor employees for experiments, and 720 civil service and 2,870 contractor employees for experiment integration. "MSFC Institutional Plan," 24 February 1969, 19/6 MSF Institutional Planning Study, Memo to Jay Foster from Dr. Lucas 1/20/69 folder, Terry Sharpe Files, Drawer 111, MSFC History Archive. Not all figures were included in the bound institutional plan; they are available on draft versions of the document in this file. Management based its projections on the assumption that MSFC manpower would increase from the current level of 5,851 to 6,900 in 1974. (Terry H. Sharpe to Lucas, 14 February 1969, *ibid.* file.) This was not an unrealistic estimate at the time, since Marshall could hardly have anticipated the toll that reductions-in-force would exact on MSFC. Instead of increasing, however, manpower plunged to less than half of that estimated in 1969. See Chapter 4 for a discussion of manpower issues in the late 1960s and early 1980s.

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- 36 Brooksbank OHI, pp. 3, 16.
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- 39 Borman left NASA for private industry, and the responsibilities of the field director’s office passed to the Headquarters Space Station Task Force under Deputy Director Douglas R. Lord. Mathews to Distribution, 17 June 1970, Space Station No. 2 1969–1970 folder, MSFC Center Directors’ Files.
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- 45 Douglas R. Lord to Kraft and Lucas, 27 May 1970; MSC E&W, “Shuttle-launched Space Station Study,” 25 June 1970, Chronological Files, Space Station Series, JSC History Office; Bill Huber, OHI by Thomas Gates/MSI, 24 September 1987, pp. 4–5.
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- 47 Paine to Rees, 21 August 1970; Stuhlinger to Rees, 12 September 1970, Space Station No. 2 1969–1970 folder, MSFC Center Directors’ Files.
- 48 “Request for Procurement Plan Approval, Space Station Phase B Extended,” 1 February 1971, Space Station No. 2 1969–1970 folder, MSFC Center Directors’ Files.
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